Department for Business Innovation & Skills

Innovation, skills and performance in the downturn

An analysis of the UK Innovation Survey 2011

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Contents

Innovation, skills and performance in the downturn. An analysis of the UK Innovation Survey 2011*

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The views expressed in this report are that of the authors and not necessarily those of the Department for Business, Innovation & Skills.

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*This work was based on data from the UK Innovation Surveys 2005, 2007, 2009 and 2011, collected on behalf of the Department for Business, Innovation and Skills (BIS)by the Office for National Statistics (ONS) and the Northern Ireland Department of Enterprise, Trade and Investment (DETI), and supplied by the Secure Data Service at the UK Data Archive. The data are Crown Copyright and reproduced with the permission of the controller of HMSO and Queen's Printer for Scotland. The use of the data in this work does not imply the endorsement of BIS, ONS, DETI or the Secure Data Service at the UK Data Archive in relation to the interpretation or analysis of the data. This work uses research datasets which may not exactly reproduce National Statistics aggregates.

Executive summary

The link between firms' innovation performance and economic cycles, especially major downturns such as that of 2008-10, is a matter of great policy significance, but is relatively under-researched at least at the level of micro data on business behaviour. It is, for example, often argued that economies need to 'innovate out of recessions' since innovation is positively associated with improvements in productivity that then lead to growth and better employment (Nesta, 2009).

The issues of how individual firms respond to downturns through their investment in innovation, and how this impacts on innovation outputs and ultimately business performance and growth during and after downturns, has been less studied because relevant data has not been readily available. The UK Innovation Survey (UKIS) 2011 now makes this possible. The UKIS 2011 with reference period 2008 to 2010 covers the downturn in economic activity generated by the global financial crash. The build-up of panels over the life of the UKIS also supports analysis of the longer-term interactions between innovation and the business cycle. This report analyses the last four waves of the surveys. Further, the latest survey includes questions on whether firms employ a specific set of skills, which adds materially to the ability to research the role of skills and human capital in innovation at the micro level.

The objectives of this report were to use data at the level of the firm to: 1) investigate the relationships between resources for innovation, innovation performance and impacts on business performance before, during and just after the economic crisis; and 2) analyse the links between a set of specific skills, covered for the first time in UKIS 2011, innovation performance and business performance.

Resources for innovation are captured in terms of specific skills, the share of graduates among employees, investment in internal and external R&D, and other knowledge, as well as innovation related expenditures on design, training, machinery and marketing. Measures of innovation performance are whether or not an enterprise introduced a new product, process, organizational/managerial change, and the share of sales generated from new products. Measures of business performance are sales per employee and changes in sales and in employment.

The main findings and the analytical and policy issues arising from them are presented in four sections:

- Resources for innovation: covering skills usage and innovation related investment
- Innovation performance: covering product, process and wider innovation activities and innovative sales
- Drivers of innovation performance: covering skills usage and other knowledge sources
- Drivers of business performance: covering skills usage and innovation performance.

The main conclusions are:

- Comparisons over time between investments in innovation related activities and innovation outputs reveal a fall during the downturn, with the exception of some business and management practices. However, innovative businesses performed better during the crisis.
- New-to-market (novel) innovation and new-to-firm (imitation) innovation are important for business performance and growth.

This implies that effective policies to nurture innovation promote business performance even during adverse economic circumstances.

- The employment of specific skills (such as product design, software development and engineering and applied sciences) generally shows a positive relationship with innovation performance during the survey period 2008 to 2010 and there is some indication that the more highly specialised of the skills (e.g. engineering and applied sciences) are distinctive drivers of innovation (not just a demand derived from innovation led by other factors).

This implies that specialised skills take-up is a legitimate feature of innovation policies both for the ability to absorb technology and external knowledge and as sources of creativity and innovation.

- Design-related as well as Science & Technology (S&T) related skills are significantly associated with innovation, and design-related skills are important for services innovation.

This implies that design is important for successful innovation and balanced policy mix should include consideration of design, both in-house and outsourced design skills and across all business sectors.

- Business performance during the downturn period was also positively correlated with innovation carried out as mixed modes (bundles of complementary activities, for example, training, management practices and intellectual property protection) and especially with modes that feature specialised skills, although the direction of causation cannot be readily inferred in one survey sample.

This implies that monolithic policies that isolate one element in the innovation system, e.g. R&D, may not meet the spectrum of innovation relevant activities and their strategic combinations.

- Regression models for growth in sales and employment during 2008 to 2010 show a significant correlation with a mode of wider innovation that features management changes. Other research by the authors (Frenz and Lambert, 2012) reports a positive link between business growth and the take up of management standards such as ISO9001, supported by accreditation.

This implies role for encouraging improved management practices as part of innovation policy e.g. through accredited management standards.

1. Introduction

The link between firms' innovation performance and economic cycles, especially major downturns such as that of 2008-10, is a matter of great policy significance, but is relatively under-researched at least at the level of micro data on business behaviour. It is, for example, often argued that economies need to 'innovate out of recessions' since innovation is positively associated with improvements in productivity that then lead to growth and better employment (Nesta, 2009).

The empirical basis for these assertions requires further work. For example, how business innovation reacts to a major contraction in demand has been examined using aggregate indicators such as the level of business spending on research and development. Official statistics indicate that, while business R&D expenditure in real terms fell from £16.5 bn in 2008 to £15.9 bn in 2009, it did so less than proportionately to the fall in GDP. There was a slight recovery to £16.1 bn in 2010, maintaining the steady R&D ratio to GDP seen in previous years, so that the R&D element in innovation at aggregate level did not record a dramatic reduction in the downturn. However, the aggregate is dominated by a relatively small number of corporations, so that expenditure by the majority of businesses might have shown a more extensive fall (Office for National Statistics, 2011).

However, others have argued that, on a broader view of aggregate expenditure on innovation, that takes into account expenditures beyond R&D conceived as intangible asset creation, the UK saw a much sharper fall in innovation investment in the downturn, with a 7%[1] fall in real terms in 2009 (e.g. Nesta, 2012). Recent empirical work on the UK Innovation Surveys point towards a substantial drop in innovation related investment in the UK in 2008 of around 8% as a result of the economic crisis (Archibugi, Filippetti and Frenz, 2013a).

The issues of how individual firms respond to downturns through their investment in resources for innovation and how this impacts on innovation performance and ultimately business performance and growth, during and after downturns has been less studied because relevant data was not readily available. The UK Innovation Survey (UKIS) 2011 now makes this possible.

In this report resources for innovation are captured in terms of specific skills, the share of graduates among employees, investment in internal and external R&D, and other knowledge, as well as innovation related expenditures on design, training, machinery and marketing. Measures of innovation performance are whether or not an enterprise introduced a new product, process, organizational/managerial change, and the share of sales generated from new products. Measures of business performance are sales per employee and changes in sales and in employment.

The report analyses the last four waves of the surveys. The Department for Business, Innovation and Skills refers to these surveys as UKIS2005, 2007, 2009

[1] A 7% drop in broader innovation expenditures is roughly twice the relative size reported in the R&D figures for 2009.

and 2011, after the year during which data was collected (Robson and Achur, 2012). The reference periods are either the three-year period – e.g. 2008-10 in the case of UKIS2011 – or the calendar year prior to data collection – e.g. the calendar year 2010 for UKIS2011.[2] When the reference period is a three-year period, the surveys measure the *propensity* of enterprises to engage in an activity. E.g., the propensity of enterprises to engage in in-house R&D in UKIS2011 is defined as the percentage of enterprises that had any in-house R&D expenditures in 2008-10. Where the reference period is the calendar year the surveys measure the *intensity* with which enterprises carry out an activity. E.g., the intensity with which enterprises engage in in-house R&D in UKIS2011 is defined as the average amount (expressed in £000s) that enterprises invested in in-house R&D during 2010.

The build-up of panels over the life of the UKIS also supports analysis of the longer-term interactions between innovation and the business cycle. The survey includes questions on whether firms employ a specific set of skills, in addition to the long established question on the share of employees with graduate or above qualifications and these enhanced skills indicators can be included in the analysis.

This study was commissioned by the Department for Business, Innovation and Skills and has been guided by a number of agreed research questions:

- *What was the scale of the effect of the downturn on investments into resources for innovation, innovation performance and enterprise performance?*
- *Which skills and which 'bundles of skills' are used intensively for which types of innovation?*
- *How does innovation performance vary with skill intensities (UKIS Q24) and types of skills employed (UKIS Q25)?*
- *What are the impacts of skills intensity and types of skills employed on enterprise performance in terms of productivity and growth?*
- *Did innovators do better during the recession?*
- *How do design skills and design investment combine to affect innovation, productivity and growth and is there a well-defined 'design led' innovation category.*

This report presents our main findings and addresses the analytical and policy issues in four sections:

- *Resources for innovation: covering skills usage and innovation related investment*
- *Innovation performance: covering product, process and wider innovation and innovative sales*
- *Drivers of innovation performance: covering skills usage and other knowledge sources*
- *Drivers of business performance: covering skills usage and innovation performance*

The more detailed statistical analyses and the data and technical issues are in the

[2] For reasons of simplicity our charts and tables state the reference period or year: 2002-4 and 2004 for UKIS2005; 2004-6 and 2006 for UKIS2007; 2006-8 and 2006 for UKIS2009; and 2008-10 and 2010 for UKIS2011.

Annexes, which also report on the specific research questions. Annex A describes the data and methodology, Annex B covers resources for innovation and Annex C looks at innovation performance. Annex D and E look at drivers of innovation performance and business performance respectively.

2. Resources for innovation

This section looks first at innovation related expenditures, including R&D and broader expenditures, before examining as a resource for innovation the range of innovation related skills employed by UK business.

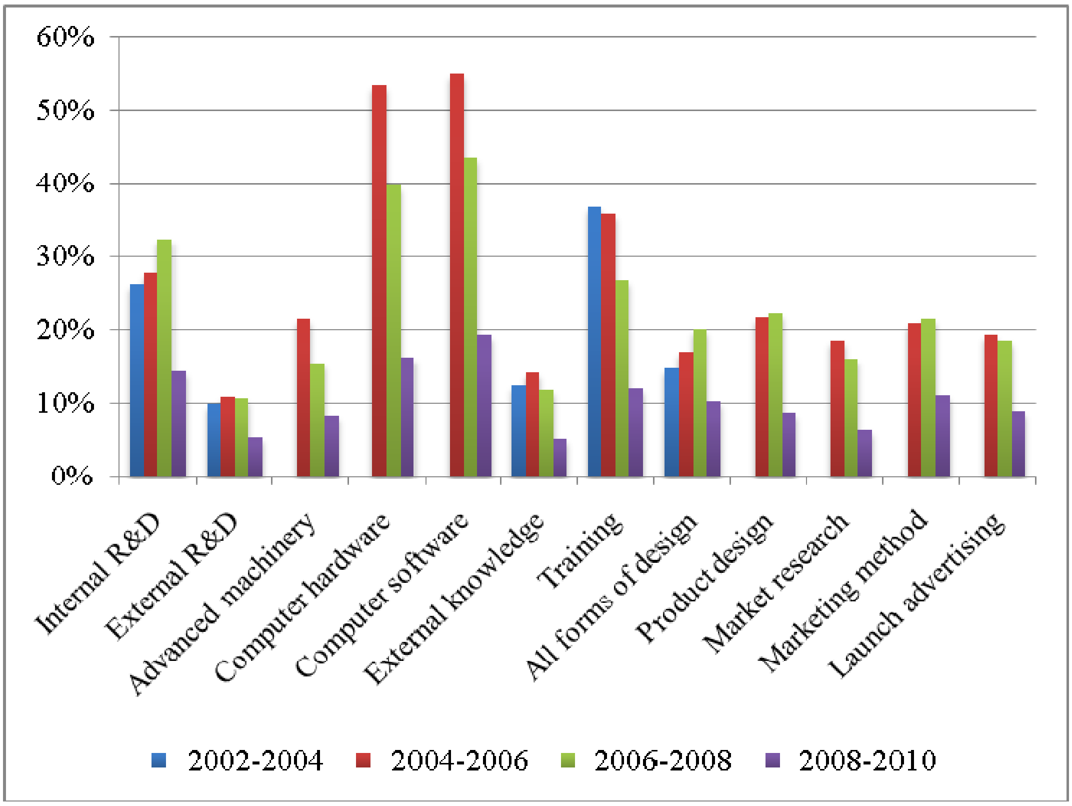
2.1 Expenditures on innovation activities

The UKIS includes several variables representing engagement in, and expenditures on, innovation directed activities, including in-house R&D; buying in R&D; expenditures on new machinery, equipment, computer hardware and software for innovation; training for innovation; design activities; and marketing of new products. Across all these types of activities, enterprises reported lower activity levels from 2008 onwards.

Our main finding is that, over the course of the survey period, 2008-10, there was a decline in both the propensity to invest in innovation (the share of enterprises that invested in innovation) and the intensity with which enterprises invested in innovation (the average amount that was spent on such activities).

Over the period covered by four successive surveys – 2002 to 2010 – there is in general (based on the full survey samples that are scaled up to the wider population) a contraction in the shares of enterprises with innovation expenditures from 2008 onwards, shown in Figure 1. The rate of contraction is also, although to lesser extent, apparent in the four-wave panel of enterprises who responded to each survey. Although the panel is not fully representative, statistically, of the successive samples, the panel data may better represent the underlying trends as they show the behaviour of the same group of enterprises over time.

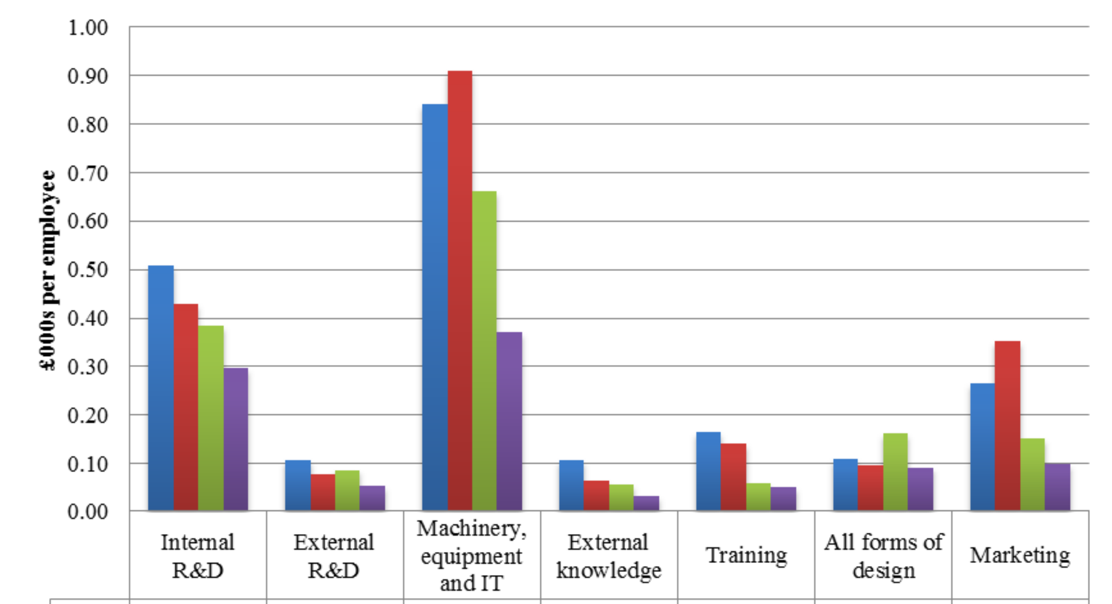
Figure 1. Share of enterprises that engage in innovation related activities in 2002-2004, 2004-2006, 2006-2008 and 2008-2010, full samples and weighted data, UK Innovation Survey



Authors' own calculations. Three-year period 2002-4 for UKIS2005; 2004-6 for UKIS2007; 2006-8 for UKIS2009; and 2008-10 for UKIS2011.

Turning to the intensities of innovation related investments for the calendar years 2004, 2006, 2008 and 2010 in Figure 2, we also see a decline during the downturn in the average amount spent per employee by enterprises on innovation related activities between 2004 and 2010. Together with fewer enterprises carrying out such activities, the average amount invested is also lower. This is in line with previous empirical work (Archibugi et al., 2013a). Some of this downwards trend appears to pre-date the financial crisis. For example, investments in internal R&D, external R&D and external knowledge were lower in 2006 than in 2004.

Figure 2. Expenditures on innovation related activities per employee, 2004, 2006, 2008 and 2010 full samples and weighted data, UK Innovation Survey



	Internal R&D	External R&D	Machinery, equipment and IT	External knowledge	Training	All forms of design	Marketing
2004	0.51	0.11	0.84	0.11	0.17	0.11	0.26
2006	0.43	0.08	0.91	0.06	0.14	0.10	0.35
2008	0.38	0.09	0.66	0.05	0.06	0.16	0.15
2010	0.30	0.05	0.37	0.03	0.05	0.09	0.10

Authors' own calculations. Calendar year 2004 for UKIS2005; 2006 for UKIS2007; 2008 for UKIS2009; and 2010 for UKIS2011.

As item non-response rates were significantly higher in UKIS2011, the numbers reported in Figure 2, can be seen as indicative of a trend but do not enable precise estimates of the extent of the reduction. The largest absolute drops in innovation investment in both 2008 and 2010 were in the amount enterprises spent on machinery, equipment and IT. The category machinery, equipment and IT had the highest investment among all categories in Figure 2. Within this category, enterprises further reported that much of it was due to upgrading of computer hardware and software (Robson and Achur, 2012). Upgrading of IT kit may be less essential to enterprises' innovation processes compared with R&D activities, while at the same time, annual IT budgets more easily adjusted downwards during periods of lower sales.

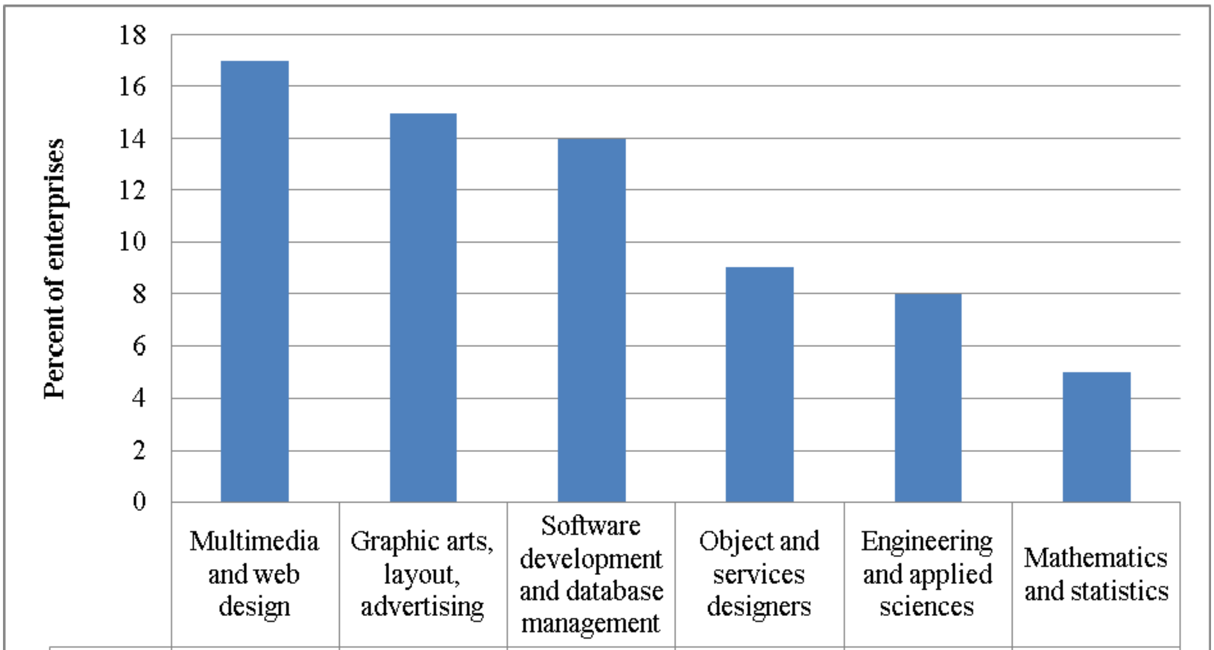
2.2 Skills for innovation

Other important resources for innovation are skills. UKIS 2011 included, for the first time, a set of questions on whether firms employ, either as staff or as external suppliers, a set of specific skills. These skills are graphic arts, product or service design, multi-media or web design, software development, engineering and applied sciences and mathematics or statistics. While not an exhaustive list of skills for innovation, these provide a useful picture of some highly relevant forms of human capital, in addition to the question on the shares in employment of graduates in science and engineering and in other subjects, that have been in the survey since

UKIS1997 (reference period 1994-1996). Our main finding is that, for the sample overall, the share of firms employing one or more of these specialised skills is low, but shows significant variation across the six types.

The overall shares of businesses employing the six specific skills are summarised in Figure 3. The analysis is based on those who answered the question on skills, so may not fully generalise to the full sample. The most frequently used skill is multimedia and web design, followed closely by graphic design, consistent with the importance of communications and on-line presentation and commerce in the modern economy and which can be considered to be the new embodiment of the traditional role of the designer in making images as part of the visualisation of the business image or appearance and usability of goods and services. The relatively high share employing software developers points to the importance of in-house as well as software purchasers. This is in-line with the results of estimates of investment in intangible assets at the aggregate level (Awano et al., 2010) which report the substantial share of own account software development in intangible investment. A slightly higher share of firms employ object and service designers than have engineering/applied science skills.

Figure 3. Share of enterprises employing specific skills, 2008-2010, full samples and weighted data, UK Innovation Survey



	Multimedia and web design	Graphic arts, layout, advertising	Software development and database management	Object and services designers	Engineering and applied sciences	Mathematics and statistics
Percent	17	15	14	9	8	5

Authors' own calculations. Percentages refer to three-year period 2008-10 for UKIS2011.

The more highly specialised skills – object and service designers, engineering and applied sciences and mathematics and statistics –are employed by far fewer businesses, and may be regarded as the more dedicated or industry specific types of skill in the survey. Software development, graphic and multimedia/web design are specialized skills for the individuals but have broader applications across industries. For example, a web presence is required by most businesses.

The overall share of the businesses who answered the question reporting use of these specific skills is low, especially amongst the more highly specialised such as mathematics and statistics. Since, as will be shown, higher shares of the more innovative businesses use these skills, a reasonable inference is that raising skills intensity could be a source of enhanced innovation performance.

3. Innovation performance

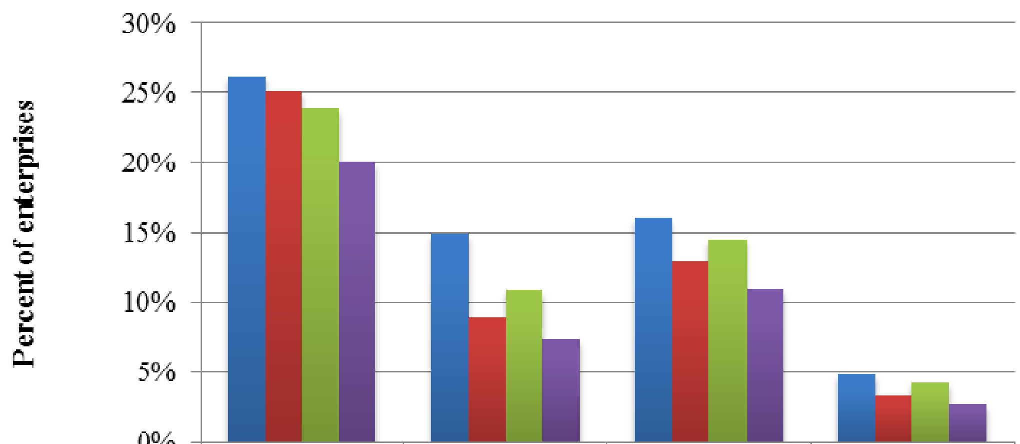
This section examines innovation performance in the area of: (i) new products (goods and services) and processes, (ii) wider innovations, consisting of new management techniques, organisational structures and marketing concepts, and (iii) innovative sales.

3.1 Product and process innovations

Innovation outputs can be defined as the share of enterprises that introduced a new product (goods or services) or a new production process or service delivery method. The main result here is that the share of enterprises with new products or processes is reported to be lower during 2008-10, than in earlier periods. However, a higher share report changes to management techniques between 2008 and 2010 than before the crisis. Introducing a quality management process suggests an objective to increase efficiency and reduce internal costs in both production and service delivery.

The analysis underlying these results is summarised in the Figures below. Figure 4 shows the shares of enterprises with product (goods or services) or process innovations. Product innovations are further distinguished into products that are new to the enterprises, and products that are not only new to the enterprise, but also the enterprise’s market – a more challenging indicator. In a similar vein, process innovations may be new-to-enterprise or new to the enterprise’s industry.

Figure 4. Share of enterprises that introduced a new product or a new process in 2002-2004, 2004-2006, 2006-2008 and 2008-2010 full samples and weighted data, UK Innovation Survey



	Product innovation	New-to-market	Process innovation	New-to-industry
2002-2004	26%	15%	16%	5%
2004-2006	25%	9%	13%	3%
2006-2008	24%	11%	15%	4%
2008-2010	20%	7%	11%	3%

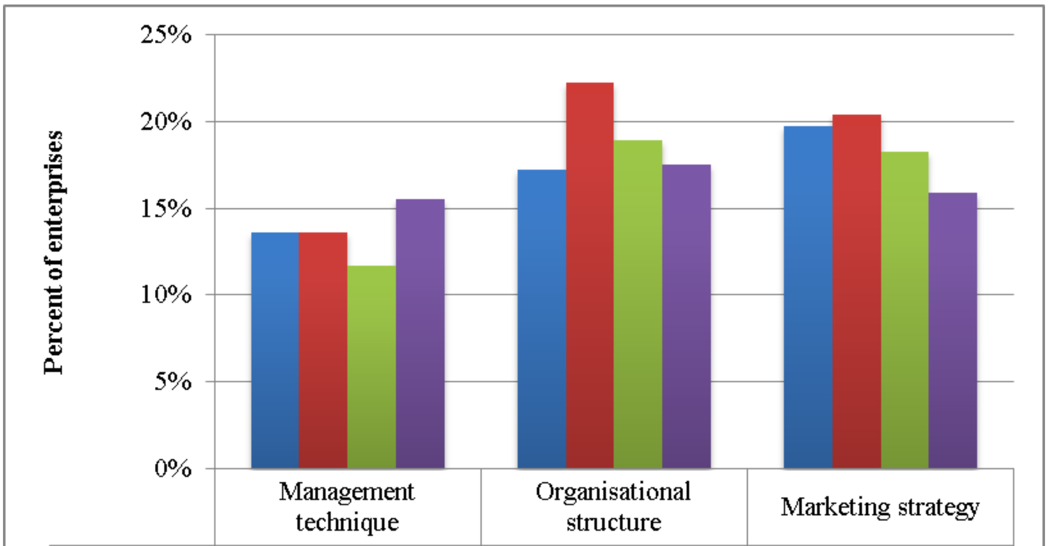
Authors' own calculations. Three-year period 2002-4 for UKIS2005; 2004-6 for UKIS2007; 2006-8 for UKIS2009; and 2008-10 for UKIS2011.

The shares of businesses reporting each type of innovation is lower in the 2008-2010 period than in the previous surveys, most markedly in new-to-market and new-to-enterprise process innovations, although it should be noted that the level of these indicators have also varied significantly over previous surveys. This, and other empirical studies, point towards lower average levels of innovation performance during and following on from the economic downturn. Evidence also suggests that, economic uncertainties, caused by downturns, have an uneven impact across different types of businesses, incumbent or new, large or small, but also across industries and technologies and geographies within the UK or via international exposure. While there might be a decline in some sectors, technologies, locations etc, other firms might "swim against the stream and increase their investment" (as suggested in Archibugi et al. 2013a: 303).

3.2 Wider innovations

The survey also collects what are frequently referred to as 'wider innovation indicators': enterprises that made changes in business or management processes, organisational structure or marketing strategy. Enterprises faced with a decline in demand for their goods or services, or with greater uncertainties about the extent and direction of future demands, could respond to such conditions with organisational restructuring, or improved costumer services through new organisational processes to add further value. Figure 5 compares the share of enterprises with wider innovations across the four survey periods.

Figure 5. Share of enterprises that introduced a new managerial technique, organisational structure or marketing strategy in 2002-2004, 2004-2006, 2006-2008 and 2008-2010 full samples and weighted data, UK Innovation Survey



	Management technique	Organisational structure	Marketing strategy
2002-2004	14%	17%	20%
2004-2006	14%	22%	20%
2006-2008	12%	19%	18%
2008-2010	16%	18%	16%

Authors' own calculations. Three-year period 2002-4 for UKIS2005; 2004-6 for UKIS2007; 2006-8 for UKIS2009; and 2008-10 for UKIS2011.

We find that the share of enterprises that introduced a new management technique, such as 6 Sigma or other quality management processes, increased between 2008-10 compared to previous periods.[3] The share of enterprises reporting new management techniques and business practices grew by around two percentage points between 2008-10. The share of enterprises that made changes to their organisational structure dropped by one percentage point and the share of enterprises that introduced a new marketing strategy dropped by two percentage points in 2008-10.

[3] The relevant question was substantially rephrased in UKIS2011 for *'management techniques'* the original question was referring to the "implementation of new management techniques within this business? e.g. Investors in People, Just in Time, 6 Sigma" which was changed to: "new business practices for organising procedures (i.e. supply chain management, business re-engineering, knowledge management, lean production, quality management etc.)"; 'organisational structure' the original question referred to: "implementation of major changes to your organisation structure? e.g. introduction of cross-site /teamworking" which was changed to: "new methods of organising work responsibilities and decision making (i.e. first use of a new system of employee responsibilities, team work, decentralisation, integration or de-integration of departments, education/training systems etc.). The question for *'marketing strategy'* remained unchanged.

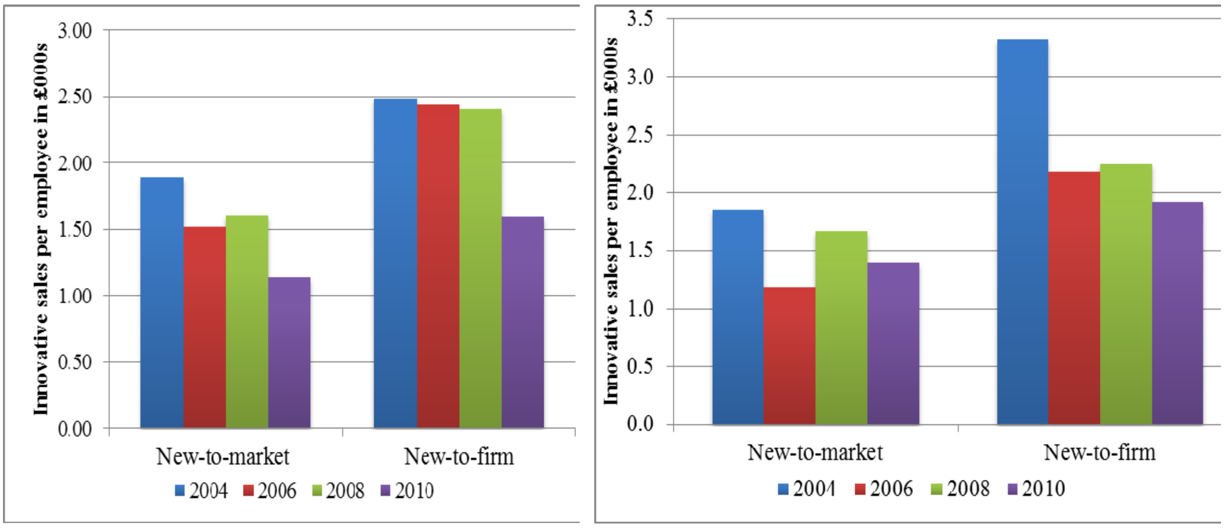
3.3 Innovative sales

We turn next to enterprises' innovation intensities, measured in the survey by the percentage of sales in a specific calendar year that are derived from (a) new-to-market products (goods and services) and (b) from products new to the enterprise but not new to the market. We use these variables to derive the actual turnover per employee derived from (a) and (b) above. This transformation is performed to avoid any distortion that may derive from single product enterprises that may report 100% of new sales.

The main result is that the surveys recorded in 2008 an increase in innovation intensities from 2006 levels, and a subsequent decline in innovation intensities in 2010. This decline appeared in both new-to-market sales and new-to-firm sales. In the full samples, innovation intensities on both measures – new-to-market and new-to-firm – in 2010 was below levels of all previous periods. Figure 6 below reports the two types of innovative sales per employee based on weighted data of full samples on the 912 enterprises in the panel.

Figure 6. Innovative sales per employee in 2004, 2006, 2008 and 2010 full samples and weighted data and panel data, UK Innovation Survey

Full and weighted samples *Panel of 912 enterprises*



Authors' own calculations. Calendar year 2004 for UKIS2005; 2006 for UKIS2007; 2008 for UKIS2009; and 2010 for UKIS2011.

4. Drivers of innovation performance

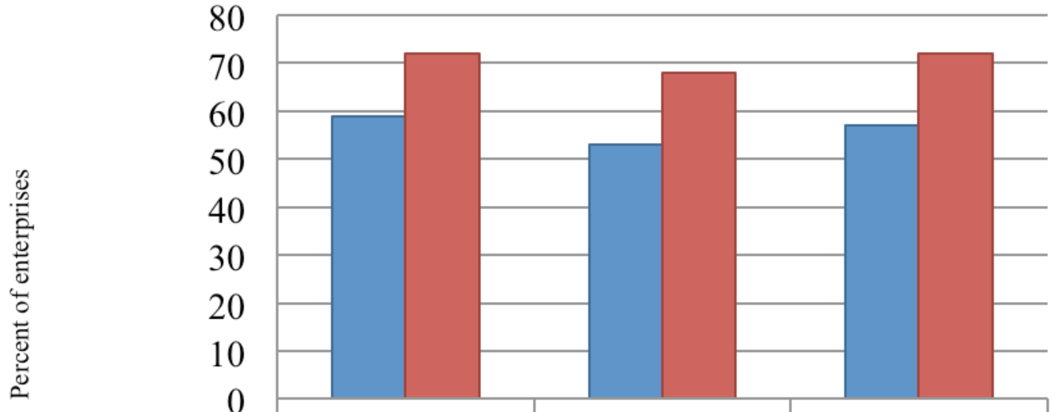
In this section we discuss first, in Sub-section 4.1, the extent to which specialised skills are correlated with business innovation. Sub-section 4.2 examines firm characteristics that best predict innovation performance before, during and following on from the crisis. Explanatory variables include firm size, age, sector, share of graduates, innovation expenditures, collaborations, and the extent to which enterprises pursue exploration strategies to open up new markets or invent new products compared with exploitation strategies to improve on existing products or production efficiencies.

4.1 Skills and innovation performance

This section presents the relationship between employment of specialised skills and the various categories of innovation, using aggregation of the six individual skills types into (a) design-related and (b) science and technology-related groups. Design-related includes graphic/art, multi-media web and product/service design. Science and technology (S&T) includes software development, science/engineering and maths/statistics. The main finding is that employment of these specific skills is much higher amongst innovators, suggesting that innovation is importantly enabled or supported by the use of appropriate skills. We can also conclude that the specific skills covered in the survey are major ingredients for successful innovation, while the more highly specialised of them appear as original or creative resources that enable innovation.

The underlying analysis looks first at the use of skills in connection with innovation involving bringing to the market or into use new or improved goods, services or processes. Figure 7 shows the share of each type of innovator who report the employment of one or more type of design skill or one or more types of S&T skill.

Figure 7. Percentages of innovators employing skills, 2008-2010, full sample and weighted data, UK Innovation Survey



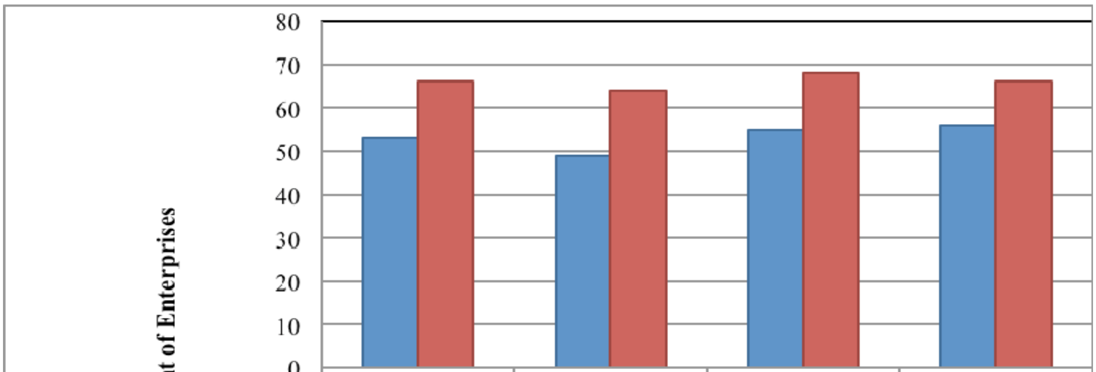
	New or significantly improved goods	New or significantly improved services	New or significantly improved processes
Share with design skills	59	53	57
Share with S&T skills	72	68	72

Authors' own calculations. Percentages refer to three-year period 2008-10 for UKIS2011.

The majority of innovators employ design or S&T skills or both, with significantly more employing S&T skills. Although a higher share of the sample as a whole report employment of design than S&T skills, for some firms, the former may be regarded as supporting business as usual more than innovation. For example, web design may be viewed as routine by many firms. Goods and process innovators were more prone to employ S&T skills, but over two thirds of services innovators use such skills, while, contrary to the widely held view that design is mostly used for the development of products rather than services, over half of services innovators employed design-related skills.

A similar picture emerges for managerial (wider) forms of innovation, in the areas of business practices, work organisation, external relationships and marketing strategy, shown in Figure 8. In each case, approximately two thirds of innovating firms employed S&T skills and around half employed design skills. Notably, the share using design skills in marketing strategy was only slightly higher than for the other practices, which shows that marketing is just one application of design.

Figure 8. Percentages of wider innovators employing skills, 2008-2010, full sample and weighted data, UK Innovation Survey



	New business practices	New method of organising work responsibilities	New method of organising external relations	Changes to marketing concept or strategy
Share with design skills	53	49	55	56
Share with S&T skills	66	64	68	66

Authors' own calculations. Percentages refer to three-year period 2008-10 for UKIS2011.

A theme in the literature on skills and innovation is to posit that demand for skills is derived from other incentives to innovation (Tether, 2005a). These include external or in-house technological change that can require particular skills as well as physical and knowledge resources to implement. By this thinking, skills adapt passively to exogenous shocks such as new technological or market opportunities. Most of the research underpinning this approach concerns the national or industry level, although it implicitly applies to the firm. Skilled people are also a resource or capability and can themselves be the creators as well as implementers of innovation in goods, services and processes. Arguably this might be expected to be the case more frequently in services than in goods production and delivery because of the tendency for service provision to involve personal interactions with users (Gallouj & Windrum, 2009).

Skills can be a capability that drives innovation or a demand derived from other determinants of innovation. These roles can be investigated through computing the ratio of the percentage of firms employing a skill (capability) with each type of innovation, to the percentage of innovators of each type who employ that skill (derived demand). These data are reported in Annex C. While derived demand dominates for the majority of these skills, in the case of the most highly specialised skills, the capability effect is predominant, for example:

- Designers of goods and services appear as drivers of new to firm innovation in goods, service and processes;
- Engineering and applied sciences appear as drivers of innovation in new to the firm goods and services and in new to industry process innovation; and
- Maths and stats employment appears as a driver in both new to the firm and new to the market or industry goods, service and process innovation.

We can conclude that the specific skills covered in the survey are major ingredients for successful innovation while the more highly specialised skills appear as original or creative resources that enable innovation.

Regression analysis can be used to relate innovation to skills and other variables. This gives a more precise picture of the extent to which the various forms of innovation are likely to depend on packages of skills (design-related skills and S&T skills), since the effects of other factors affecting innovation performance can be taken into account[4]. Some of the skill dependencies that emerge are unexpected and provide new insights into the importance of different types of human capital in the underlying processes that enable and support innovation. (The regression results are in Annex C). The main findings from applying regression models include:

- **incremental goods innovation and services innovation are positively correlated with employment of design skills**, but not significantly related to pure S&T skills. This may seem surprising as goods innovation might be expected to rely on engineering and science capabilities. However, incremental – new-to-firm but not new-to-market – goods and services innovations often take the form of adaptation to new or different uses without requiring significant technical change;

- **the frequency of novelty (new-to-market innovation) in goods is significantly related to the employment of S&T skills** but not design skills. The implication here is the importance of technology and the availability of the human knowledge that is part of it, in enabling leading edge developments in physical goods;

- **a striking and unexpected feature of these results is the consistently positive correlation between design skills and novel (new-to-market) service innovation**. It is frequently assumed in innovation studies that design is basically an addition to affect the appearance of goods where the basics of change derive from other factors. And design is rarely, if ever, studied in the context of innovation in services;

[4]In this section design skills includes software development, which is a variation from the groups used in Section 2.2. The amended grouping follows from the strength of the statistical association between the separate skills variables. See Annex D for details.

- **there is less clear evidence of process innovation correlating with specialised skills**, perhaps indicating the extent to which process improvements might be more strongly determined through other factors, such as bought-in equipment and external services; and

- **incremental (new-to-business) process innovation is correlated with employment of design skills**, indicating the role of adapting external knowledge to the firm's particular circumstances, but S&T skills are not significant.

Turning to wider innovation, in the form of new business practices, changes to work organisation, changes to external relations and changes to marketing concepts or strategies, there are statistically significant correlations between each type of these wider innovations and design and S&T skills, with the exception of a lack of relationship between 'changing marketing concept or strategy' and S&T skills, which is consistent with our expectations. The significance and size of the link is particularly strong for innovation through 'changes to work organisation' and design skills, suggesting the breadth of applicability of these skills in business.

From our analysis, it is notable that the share of firms using design skills in marketing strategy is only slightly higher than for the other forms of 'wider innovation,' consistent with the idea that marketing is just one application of design and not its essential function.

Turning to innovation intensities measured as the share of new-to-market goods and services in sales, there is a positive and significant association with the joint employment of design and S&T skills. This suggests that higher levels of innovativeness are not just dependent on expenditure on R&D and other inputs, but are actively enabled by using specialised skills in appropriate combinations. When analysing the share of innovative sales in services, the theme of a strong correlation of services innovation with design skills emerges clearly again, with a comparatively large coefficient in the novel services innovation intensity equation.

4.2 Drivers of innovation performance over time

In this section we look at a set of enterprise characteristics that influence innovative sales. Figure 6 showed that innovative sales – measured as new-to-firm and new-to-market sales – fell in 2010, following the decline in innovation investment in 2008. Here, the aim is to uncover if different enterprise characteristics, including innovation investment are more or less important before, during and following on from the crisis.

Economic crises have been linked to the emergence of new, disruptive technologies that trouble those who are experts in the use of old, established technologies (Schumpeter, 1911; Dosi, 1982). In Schumpeter's words "it is not the owner of stage-coaches who builds railways" (1911, p.66). This implies that the type of business with high innovation intensity can differ in periods of relative calm from periods following economic turmoil. It is not clear if the current economic crisis can be associated with such a pattern. Nor, is it clear if changes in the identity of innovators could be visible at the aggregate level of the UKIS.

Empirical evidence based on the current economic crisis is both scarce and mixed. Kanerva and Hollanders (2009) find that highly innovative businesses continued to invest in innovation during the downturn. Archibugi et al. (2013b: 1,247) report that before the crisis "incumbent enterprises are more likely to expand their innovation investment, while after the crisis a few, small enterprises and new entrants are ready to 'swim against the stream' by expanding their innovative related expenditures".[5]

The results presented in this report point towards stability in the make-up of innovators. Our findings suggest that enterprises with high innovation performance, measured by new-to-firm sales per employee as well as new-to-market sales per employee, have higher innovation investments before, during and following on from the crisis. Successful innovators also tend to be more likely to compete in international markets.

We regressed innovative sales (measured as new-to-firm sales per employee and new-to-market sales per employee, with both measures expressed in £000s) on innovation investment intensity (total innovation related expenditures per employee expressed in £000s) and an extensive set of additional explanatory variables. '*Before the crisis'* refers to the calendar year 2006, '*during the crisis'* to the calendar year 2008 and *'following on from the crisis'* to 2010. Innovative sales are lagged by one survey round (by two years).

Before the crisis *t=2006*	*During the crisis* *t=2008*	*Following on from the crisis* *t=2010*
Innovative sales in 2006 ↑ Innovation related investments and firm characteristics in 2004	Innovative sales in 2008 ↑ Innovation related investments and firm characteristics in 2006	Innovative sales in 2010 ↑ Innovation related investments and firm characteristics in 2008

Table 1 below presents the relevant regressions results with respect to the measure new-to-firm sales per employees.[6] The results for new-to-market sales are commented on in this section only. The full regression results are presented in Appendix D, Table D.15.

The first column of Table 1 presents the regressions predicting new-to-firm sales in 2006, the second and third columns predict new-to-firm sales per employee in 2008 and 2010 respectively. New-to-firm sales in 2006 is explained with a set of independent variables that include total innovation related expenditures (labelled 'innovation investment') and that are measured in the previous survey for the calendar year 2004. During the crisis we measure new-to-firm sales in 2008 and the explanatory variables in 2006, and following on from the crisis we look at new-to-firm sales in 2010 with the explanatory variables measured in 2008.

[5] Both Kanerva and Hollanders and Archibugi at al. (2013b) analysed the activities of European enterprises using Innobarometer data compiled by the European Commission in 2009.
[6] The results are also discussed in Appendix D, Table D.15.

Table 1. New-to-firm sales per employee before (2006), during (2008) and following on from the crisis (2010), UK Innovation Survey

Dependent variables	New-to-firm sales per employee t		
Independent variables	2006	2008	2010
Innovation investment t-1	0.21**	0.19**	0.09+
	(0.045)	(0.053)	(0.055)
Employment t-1	0.04	0.03	-0.01
	(0.026)	(0.024)	(0.028)
Newly established	0.17	0.05	0.19
	(0.110)	(0.101)	(0.143)
Group belonging	-0.06	-0.03	0.11
	(0.061)	(0.063)	(0.071)
International market t-1	0.14+	0.16*	0.07
	(0.073)	(0.082)	(0.069)
Cooperation with other business t-1	-0.15	0.50**	0.04
	(0.142)	(0.177)	(0.122)
Cooperation with research institute t-1	0.20	-0.23	0.09
	(0.177)	(0.227)	(0.168)
Explorative strategies t-1	0.11+	0.10	0.08
	(0.057)	(0.075)	(0.103)
Exploitative strategies t-1	0.00	0.04	0.11+
	(0.062)	(0.085)	(0.059)
Finance t-1	-0.02	0.03	-0.02
	(0.086)	(0.102)	(0.093)
Skills t-1	0.31*	0.01	0.16
	(0.144)	(0.097)	(0.109)
Industry dummies	Included	Included	Included
Constant	-0.14	-0.20	0.29
	(0.231)	(0.253)	(0.267)
Observations	696	760	564
R-squared	0.210	0.188	0.184
F-statistic	5.16**	5.16**	3.20**

Regression method is OLS. We report regression coefficients with robust standard errors in parentheses. The dataset is the panel of 912 enterprises that responded to UKIS 2005, 2007, 2009 and 2011. The number of observations is smaller than 912 due to missing values. New-to-firm sales are measured in the calendar years 2006, 2008 and 2010.
** p<0.01, * p<0.05, + p<0.1

There is some indication (p<0.1) that the exploitation of previous innovations and competencies, through further quality improvements to existing products and efficiency gains in production processes, are associated with higher new-to-firm sales in 2010.[7] The finding is in contrast to Archibugi et al. (2013a) who found exploration to better predict innovation investments of UK businesses in 2008.

Newly established enterprises reported lower new-to-market sales following on from the crisis (the regressions predicting new-to-market sales are reported in Annex D Table D.14), suggesting, in line with Kanerva and Hollanders (2009), that established players had higher new-to-market sales.

[7] Note that we measure innovation intensity here as new-to-firm sales per employee. For new-to-market sales explorative strategies – long-term activities aimed at developing new markets and new products – correlate with innovation intensity. The related results are reported in Annex D Table D.14.

Operating in international markets is positively associated with new-to-firm sales during the crisis. Enterprises that operate abroad may have innovation advantages *per se*, because they learn from different local environments, or perceive a greater need to upgrade their products more frequently in order to compete in different markets (e.g. Frenz and Ietto-Gillies, 2011). Producing and selling in a number of countries could, at least to some extent, mitigate the impact of the crisis on those firms, because uncertainties and risks are spread more widely over a number of locations/markets.

Our main finding is the following: total innovation related expenditures per employee are positively correlated with new-to-firm sales before, during and following on from the crisis. However, following on from the crisis both the coefficient size and significance are lowest. This suggests that innovation investments matter, but that the extent to which businesses reap the benefits from investments in innovation in terms of generating new-to-firm sales declined during the downturn.

Breaking down the innovation related expenditures into individual components we find that among the different innovation expenditure types in-house R&D and design expenditures better predict new-to-firm sales than any of the remaining investment types. The related regression results are presented in Annex D, Table D.16.

5. Drivers of business performance

This section examines the extent to which innovation performance correlates with business performance before, during and following from the crisis. We then examine how specific design and Science and Technology (S&T) skills might feed through into improved business performances.

5.1 Drivers of business performance over time

Business performance is measured using a proxy for labour productivity (sales per employee) and change in employment.[8] Our main findings are that new-to-market innovation and new-to-firm innovation are important for business performance and growth.[9]

During the crisis in 2008, innovative sales – new-to-firm and new-to-market – are positively correlated with growth in employment. New-to-firm sales are also correlated with turnover per employee, a very basic measure of labour productivity,

[8] In the extended Appendix E we also report on change in turnover as a measure of business performance. The results are reported in Tables E.3 and 4.

[9] The regressions for new-to-firm sales predicting sales per employee and change in employment are those presented in this section in Tables 2 and 3. The regressions for new-to-market sales predicting sales per employee are reported in Appendix E Table E.2 and change in employment in Table E.6.

during the crisis.

Based on this and our overall results, we believe that (a) firms with high innovation intensity fare better during periods of economic turmoil, but that (b) the benefits that firms can reap from innovation are greater during periods of relative calm. This is compounded by the findings reported in the previous section: the returns on innovation investments in terms of innovative sales are also lower during an economic crisis.

We report the regression estimates for productivity in Table 2. Innovation performance –new-to-firm sales per employee – is measured in the same year as productivity. The remaining explanatory variables, including skills, are measured in the previous survey reference year.

Table 2. Sales per employee before (2006), during (2008) and following on from the crisis (2010), UK Innovation Survey

Dependent variables	Sales per employee t		
Independent variables	2006	2008	2010
New-to-firm sales per employee t	0.50**	0.18*	0.21+
	(0.151)	(0.092)	(0.121)
Employment t-1	-0.05+	-0.08**	-0.11**
	(0.028)	(0.028)	(0.036)
Skills t-1	0.28*	0.55**	0.45**
	(0.130)	(0.079)	(0.093)
International market t-1	0.34**	0.42**	0.37**
	(0.087)	(0.079)	(0.094)
Group belonging	0.32**	0.25**	0.34**
	(0.069)	(0.064)	(0.085)
Industry dummies	Included	Included	Included
Constant	4.13**	4.46**	4.54**
	(0.208)	(0.206)	(0.280)
Observations	634	634	406
R-squared	0.456	0.472	0.433
Chi-squared	631.9	570.2	318.3

Regression method is by two stage least squares. We report regression coefficients with robust standard errors in parentheses. The dataset is the panel of 912 enterprises that responded to UKIS 2005, 2007, 2009 and 2011. The number of observations is smaller than 912 due to missing values. The first stage equation is that reported in Table 1. Sales per employee are measured in the calendar years 2006, 2008 and 2010.
** p<0.01, * p<0.05, + p<0.1

New-to-firm sales per employee are positively correlated with productivity in all three periods. In other words, enterprises with higher innovative sales also performed better in terms of productivity. The pre-crisis relationship is stronger compared with during and following on from the crisis. This suggests that, while innovators fare better during the recession, the benefits that they take during periods of economic growth are also greater.

The share of graduates (the variable labelled skills) positively correlates with productivity. Here the relationship is strongest during and following on from the crisis.

Furthermore, those firms reporting highest sales per employee before and throughout the economic downturn are those that operate internationally and are more likely to belong to a wider company group. We turn next to performance measured as the changes in employment, expressed as a function of innovation performance.

Table 3. Change in employment before (2006), during (2008) and following on from the crisis (2010), UK Innovation Survey

Dependent variables	Change in employment t		
Independent variables	2006	2008	2010
New-to-firm sales per employee t	0.22*	0.15*	0.10
	(0.108)	(0.067)	(0.094)
Employment t-1	-0.23**	-0.12**	-0.13**
	(0.022)	(0.019)	(0.025)
Skills t-1	-0.22*	-0.02	-0.05
	(0.092)	(0.055)	(0.069)
International market t-1	-0.23**	-0.01	-0.00
	(0.066)	(0.054)	(0.067)
Group belonging	0.16**	0.03	0.01
	(0.054)	(0.044)	(0.060)
Industry dummies	Included	Included	Included
Constant	1.28**	0.66**	0.70**
	(0.166)	(0.142)	(0.198)
Observations	694	697	469
R-squared	0.156	0.027	0.062
Chi-squared	192.0	56.86	41.36

Regression method is by two stage least squares. We report regression coefficients with robust standard errors in parentheses. The dataset is the panel of 912 enterprises that responded to UKIS 2005, 2007, 2009 and 2011. The number of observations is smaller than 912 due to missing values. The first stage equation is that reported in Table 1. Change in employment is measured between the calendar years 2004 and 2006, 2006 and 2008, and 2008 and 2010.
** $p<0.01$, * $p<0.05$, + $p<0.1$

New-to-firm sales are positively correlated with growth in employment before the crisis and during the crisis (2008) but not following on from the crisis. Generally, the significance and explanatory power of these models (the R-squared) for 2008 and 2010 are lower, suggesting that factors other than innovative sales were more important in determining growth over these periods. Notably, we could not include a variable that captured the change in demand conditions, and it is likely to be changes in demand structures across different markets that explain changes in employment numbers. The crisis had a disruptive effect on the links between innovation and economic performance and the potential longer-term benefits of maintaining innovative efforts during the downturn may not be evident in business data for 2010. The next section includes some models that are based on a wider selection of innovation indicators from the survey.

5.2 Drivers of business performance: skills

Innovation has multiple dimensions and is not always best represented by a single variable from the survey. For the analysis of the relationships between skills and economic performance indicators, we use a methodology of identifying 'mixed modes of innovation' which are sets or bundles of activities, undertaken together by a firm to bring about and market a new good or service, or improve on production, delivery and business processes. The estimation of modes rests on the empirical evidence of complementarity between innovation inputs, linkages and outcomes.

This methodology has been developed from earlier work under OECD auspices (Frenz and Lambert, 2009). Modes can be conceived as strategic orientations or styles of innovation. The methodology for computing the modes from many variables taken from the UKIS 2011 is discussed in detail in Annex E.

One of the mixed modes derived from the UKIS 2011 data is substantially determined by design-related skills, while S&T skills combine with the following activities: in-house and bought in R&D and other knowledge; product design; and the use of intellectual property rights in an in-house technology based strategy. The business performance indicators are the same as in the previous section: a proxy for labour productivity – sales per employee – and change in sales and in employment in 2010.

Our main findings are that: (a) the skills modes, both around technology and IP, as well as around design skills, are strongly correlated with sales per employee and change in sales in 2010; and (b) that both modes are, albeit to a lesser extent, correlated with growth in employment in 2010. This is in line with the regressions reported in the previous sections, where too, innovation and skills were good predictors of sales per employee in 2010.

Table 4 shows the make-up of six innovation modes, two of which – Modes 1 and 4 – are skills driven. All six modes are used to predict productivity and employment growth. In Table 4, the variables that feed into the modes are those whose correlations with a specific mode take values of 0.5 or higher. These values are indicated (highlighted red) in Table 4. Based on this, we see that software development is more highly correlated with the design skills than with S&T and forms part of the 'design skill led mode' – Mode 4. Science and technology skills unsurprisingly are correlated with other technology indicators in Mode 1. The pure design skill of product and service design shows a secondary loading with the technology mode, again emphasising that design is a complementary resource for technological innovation as well as a source of non-technological creativity.

Table 4. Mixed innovation and skills modes based on UKIS 2011

Modes *Variables feeding into the modes*	*Mode 1* Technology and IP driven mode	*Mode 2* Codified knowledge	*Mode 3* Wider innovating	*Mode 4* Design skills driven	*Mode 5* Market facing	*Mode 6* External process modernizing
New product	0.2	0.0	0.1	0.1	0.8	0.0
New process	0.1	0.2	0.4	0.1	-0.3	0.5
New-to-market product	0.4	0.1	0.1	0.1	0.6	0.3
New business practice	0.1	0.2	0.7	0.0	-0.1	0.2
New management technique	0.0	0.1	0.8	0.1	-0.1	0.1
New business structure	0.1	0.1	0.7	0.1	0.1	0.0
New marketing strategy	-0.1	0.1	0.7	0.2	0.3	-0.2
In-house R&D	0.7	0.3	0.3	0.1	0.2	-0.1
Bought in R&D	0.5	0.2	0.4	0.1	0.2	0.1
Machinery, equipment and IT	0.2	0.1	0.3	0.1	0.1	0.5
Training	0.3	0.1	0.5	0.0	0.1	0.3
Design expenditures	0.5	0.2	0.3	0.2	0.3	-0.1
Marketing expenditures	0.2	0.2	0.5	0.2	0.5	-0.2
External innovating	-0.3	0.0	-0.1	0.1	0.4	0.6
Cooperation	0.4	0.6	0.2	0.1	0.0	0.1
Information from other businesses	0.0	0.8	0.0	0.2	0.0	0.0
Information from universities	0.3	0.8	0.1	0.1	0.0	0.0
Standards	0.0	0.9	0.0	0.1	0.1	0.0
Publications	0.2	0.8	0.1	0.1	0.1	0.1
Patents	0.9	0.2	0.0	0.0	0.1	-0.1
Design right	0.8	0.0	0.1	0.2	0.1	0.0
Copyright	0.6	0.1	0.1	0.3	0.1	-0.1
Graphic Artists	0.1	0.1	0.1	0.9	0.1	0.0
Design of objects and services	0.5	0.1	0.0	0.6	0.1	0.0
Multi-media/web	0.1	0.1	0.1	0.9	0.1	0.0
Software development	0.3	0.1	0.1	0.7	-0.1	0.2
Engineering/applied sciences	0.7	0.2	-0.1	0.1	-0.1	0.2
Mathematics and statistics	0.5	0.1	0.0	0.4	-0.1	0.4

Modes 1 to 6 are now used to predict productivity and changes in employment in Table 8. It is important to note that business output and employment growth might be negative over the period, due to the recession, but positive and significant coefficients on any of the explanatory variables indicate that they have at least an offsetting effect and are associated with output or employment growth greater than it would otherwise have been.

Table 5. Regression model for sales per employee, change in sales and employment, with mixed modes using UKIS 2011

Dependent variable *Independent variables*	Sales per employee 2010	Change in sales 2008 - 2010	Change in employment 2008 - 2010
Technology and IP driven	0.54**	0.229**	0.06**
	(0.05)	(0.04)	(0.02)
Codified knowledge	0.19**	0.14**	0.05**
	(0.03)	(0.02)	(0.01)
Wider innovating	0.02	0.129**	0.09**
	(0.03)	(0.02)	(0.01)
Design skills driven	0.34**	0.229**	0.06**
	(0.03)	(0.03)	(0.01)
Market facing	-0.10**	0.03	0.02
	(0.03)	(0.02)	(0.01)
External process modernizing	0.15**	0.161**	0.07**
	(0.04)	(0.03)	(0.01)
Employment	0.93**	-0.13	-0.04**
	(0.01)	(0.01)	(0.01)
Industry dummies	Included	Included	Included
Observations	8,136	7,892	8,021
R-squared	0.71	0.11	0.04
F-statistic	1,034.00	16.00	14.65

Authors' own calculations. Regression method is OLS. We report regression coefficients with standard errors in parentheses. Sales per employee refers to the calendar year 2010; and changes in sales to the change from 2008 to 2010. The data is the UKIS2011.
** p<0.01, * p<0.05, + p<0.1

The regression on sales per employee shows a positive association with the modes except for market facing and wider (managerial and organisational) innovation. There are also significant relationships with the design skills and the technology and IP driven mode that includes science and technology skills. Currently observed wider innovation is not significant in the productivity equation, which lends some support for the idea found in the management and innovation literature that managerial innovation may have a negative effect on current productivity by diverting management attention to the internal change process (Crespi, Criscuolo and Haskel, 2007).

For the final column estimating change in employment, the design led and technology and IP driven modes are, although somewhat smaller than in the other equations, positively correlated. A positive link between growth and the innovation strategy indicators over the downturn supports the thinking that innovation can ameliorate the impact of a recession. Together with the links between skills and innovation indicators this suggests that skills are both innovation and performance enabling. Especially important is the impact of skills driven innovating on growth during the downturn. Firms using, as part of their human capital, packages of specialised skills, show significantly better growth of output or employment in very difficult economic conditions. A striking feature of these models is that the ‘wider innovation’ mode is significantly related to growth indicators but not to productivity levels. This seems to contradict the expectation about the motivation for managerial innovation – that it is cost saving, which should be reflected in productivity. However it is consistent with other analyses by the authors:

- The ‘wider innovation’ mode measured in 2006-2008 is significantly correlated with growth over that period (Annex E, Table E 7)
- The use of good management practices codified in standards such as ISO 9001 supports innovation and shows a significant correlation with growth in employment (Frenz and Lambert, 2012, Tables 5.4 and 5.7).

Over the downturn period itself, the indicators of the shares of graduate employment – here standing both for skills intensity and for generic skills – do not emerge as significant in the growth equations. However the graduate employment share is a significant variable in the longer run innovation and performance relationships reported in Section 5.1.

We have presented a range of analytical models that relate innovation to design indicators and economic performance to modes of innovation that are characterised by, or strongly feature, design. The degree of significance suggests that design can be seen as a key creative element in innovation in firms and in the national innovation system, where it also plays a leading role in linking other innovation determinants with business, market and economic outcomes. This pervasiveness is in stark contrast with the frequent treatment of design as an ancillary to innovation.

The models of innovation performance include substantial and statistically well determined correlations between design – including skills and investment – and most other innovation indicators. This is in line with the results of the Design Council surveys which suggest design is a significant capability across the range of innovation outcomes. This is in contrast to the way design is understood and measured in mainstream innovation analysis and metrics systems. For example, the international standard for innovation measurement – the Oslo manual – recognises that design is part of the complete innovation process but for measurement purposes stresses its role in marketing innovation as a way of varying presentation of a product without affecting its functional or user characteristics.

6. Conclusions and policy implications

- Comparisons over time between investments in innovation related activities and innovation outputs reveal a fall during the downturn, with the exception of some business and management practices. However, innovative businesses performed better during the crisis.
- New-to-market (novel) innovation and new-to-firm (imitation) innovation are important for business performance and growth.

This implies that effective policies to nurture innovation promote business performance even during adverse economic circumstances.

- The employment of specific skills (such as product design, software development and engineering and applied sciences) generally shows a positive relationship with innovation performance during the survey period 2008 to 2010 and there is some indication that the more highly specialised of the skills (e.g. engineering and applied sciences) are distinctive drivers of innovation (not just a demand derived from innovation led by other factors).

This implies that specialised skills take-up is a legitimate feature of innovation policies both for the ability to absorb technology and external knowledge and as sources of creativity and innovation.

- Design-related as well as Science & Technology (S&T) related skills are significantly associated with innovation, and design-related skills are important for services innovation.

This implies that design is important for successful innovation and balanced policy mix should include consideration of design, both in-house and outsourced design skills and across all business sectors.

- Business performance during the downturn period was also positively correlated with innovation carried out as mixed modes (bundles of complementary activities, for example, training, management practices and intellectual property protection) and especially with modes that feature specialised skills, although the direction of causation cannot be readily inferred in one survey sample.

This implies that monolithic policies that isolate one element in the innovation system, e.g. R&D, may not meet the spectrum of innovation relevant activities and their strategic combinations.

- Regression models for growth in sales and employment during 2008 to 2010 show a significant correlation with a mode of wider innovation that features management changes. Other research by the authors (Frenz and Lambert,

2012) reports a positive link between business growth and the take up of management standards such as ISO9001, supported by accreditation.

This implies role for encouraging improved management practices as part of innovation policy e.g. through accredited management standards.

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Annex A Data and methodology

Annex A first discusses the UK Innovation Surveys (UKIS). In particular, we discuss the latest UKIS2011, extensively used in the report, and compare the characteristics of UKIS2011 with that of the panel of around 900 enterprises that responded to all four waves of the survey. In the final section we discuss the methods used to analyse the data: basic descriptive statistics, regressions and factor analysis.

A.1 The UK Innovation Surveys

The UKIS provide direct responses from enterprises about their innovation and related activities. The UKIS 2011 has content that can be used for new lines of inquiry into subjects of great economic and policy interest. First, as the reference period, 2008 to 2010 covers the downturn in economic activity generated by the global financial crash, there is the opportunity to look at the level and effects of innovation over that period. The build-up of panels over the life of the UKIS also supports analysis of the longer-term interactions between innovation and the business cycle. Second, the latest survey includes questions on whether firms employ a specific set of skills, in addition to the long established question on the share of employees with graduate or above qualifications. This adds materially to the ability to research the role of skills and human capital in innovation at the micro level.

The surveys, currently in their 7th round, are collected by the Office for National Statistics and the Northern Ireland Department of Enterprise, Trade and Investment on behalf of the UK Department for Business, Innovation and Skills. Questionnaire and survey designed are based on a harmonized approach across European countries, with country-specific adaptations, and the UK Innovation Surveys are the UK version of the so-called Community Innovation Survey (CIS) that is carried out in most European countries. In Work package 2 we explore a set of questions unique to the UK questionnaire on a wide range of skills – science and engineering, multimedia and web-design, software development and database management, object and service design etc. (e.g. Robson and Achur, 2011).

The sample frame is the Inter-Departmental Business Register. Sampled are all those enterprises with 10 or more employees. Samples are stratified by three size bands, 2-digit industry sectors and 12 UK regions. Response rates of the surveys are typically high, around 50%. Questionnaires are administered via pen and paper, with follow up interviews on non-responses. For further information on the survey methodology, see, for example, Robson and Kenchatt, 2009 and Robson and Achur, 2011.

In the project we use the last four waves of the surveys, which were collected in 2005, 2007, 2009 and 2011, and are referred to as UKIS2005, 2007, 2009 and 2011. Reference periods are: (i) a three-year period, e.g. 2008 to 2010 in UKIS2011; or (ii) the calendar year prior to the data collection, e.g. in the case of UKIS2011 the year 2010. Because we are interested at comparing patterns and relationships before, during and following on from the economic downturn, we are using the last four waves of the surveys.

A.2 The UK Innovation Survey 2011

We analyse UKIS2011 data, and the reference period covers the years during the downturn period 2008 to 2010. UKIS2011 has included, for the first time, a set of questions on whether firms employ, either as staff or as external suppliers, a set of specialised skills. These specialised skills are graphic arts, product or service design, multi-media or web design, software development, engineering and applied sciences and mathematics or statistics. While not an exhaustive list of skills for innovation, these provide a useful picture of some highly relevant forms of human capital, in addition to the question on the shares in employment of graduates in science and engineering and in other subjects, that have been in the survey since UKIS2 in 1997.

The report by Robson and Achur (2011) on the first findings from the UKIS2011 highlights issues of comparability across the different waves of the survey. They conclude that responses between UKIS2005 to 2009 are likely to have higher levels of cross-survey reliability. In UKIS2011 two factors in the data collection technique pose a greater threat to the comparability of UKIS2011 replies with the previous three waves: (a) a larger share of interviews, around 50%, was carried out over the phone; (b) the move to SIC2007, specifically updated categories in services, together with a rotation in the sample, resulted in an increase in new recipients. 5% of respondents of UKIS2011 also responded to UKIS2009, while there around half of businesses that replied to UKIS2009 also replied to UKIS2007.[11] (b) in particular, but also (a) are possible explanations why there is an increase in item non-response in UKIS2011. Non-responses specifically affect questions around estimating expenditures or sales in £ or giving providing information on the number of employees (which half the respondents did not provide), but the returns in their entirety are affected. Due to possible 'learning' effects of businesses that completed more than one questionnaire, there are fewer item non-responses in the panel of 912 enterprises, making their responses more comparable over time, although potentially less representative of the UK business population. The next section compares the characteristics of the panel with that of UKIS2011.

[11] Robson and Achur state that "[w]ith a large proportion of businesses receiving the survey for the first time, we have also noticed a higher item non-response on this occasion. (Note: around half of responses in UKIS 2009 were common to the previous survey in 2007 against less than a fifth common to UKIS2011 and the previous survey in 2009.) Whereas previous surveys were showing respondents were 'learning' how to complete the form and demonstrating a good understanding of the questions and what was meant by innovation. In this respect, the latest data is more comparable to data from the CIS3 survey conducted in 2001, where respondents were also new to the survey." (2012: 5)

A.3 The panel between UKIS2005, 2007, 2009 and 2011

In the report we analyse the full surveys scaled up to be representative of the UK enterprise population with 10 and more employees (excluding public services), but also make use of the panel, those 912 enterprises that responded to all four surveys. We use the panel for two reasons: first, because we believe that there is greater comparability in the answers of those 912 enterprises over time, as per our discussion in the previous section; secondly, we use a lag structure between inputs and outputs of innovation in some of the regression analyses. While there might be improved comparability of the answers of those 912 enterprises across the four surveys, the panel is not representative of the UK population, specifically with respect to enterprise size, as businesses responding to all four surveys are more likely to be large. Table A.1 and A.2 compare the distribution of enterprises in the panel with that in UKIS2011 – unweighted and weighted data.

Table A.1 Size distribution of enterprises in the panel and UKIS2011

	Panel		UKIS2011 unweighted		UKIS2011 weighted	
	Frequency	*Percent*	*Frequency*	*Percent*	*Frequency*	*Percent*
Small	58	6	4,897	34	7,099.05	50
Medium	244	27	2,469	17	1,337.83	9
Large	610	67	6,976	49	5,905.13	41
Total	912	100	14,342	100	14,342	100

*small enterprises are those with 10 to 49 employees, medium sized are enterprises with 50 to 249 employees, and large are enterprises with more than 250 employees.

The weighted UKIS2011 projects that around 50% of enterprises are small businesses with 10 to 49 employees. Of the actual UKIS2011 responses 34% are small, but in the panel this is further reduced to 6%. Table A.2 looks at the sectoral distribution of the panel compared with UKIS2011.

Table A.2 Sector distribution of enterprises in the panel and UKIS2011

	Panel		UKIS2011 unweighted		UKIS2011 weighted	
	Frequency	*Percent*	*Frequency*	*Percent*	*Frequency*	*Percent*
Manufacturing	204	22	2,849	20	2,490.53	17
Services	638	70	9,845	69	10,202.91	71
Total	912	100	14,342	100	14,342	100

* Mining and quarrying, utilities and construction are omitted from the table.

There is a slight bias towards manufacturing enterprises in the sample. In UKIS2011 the changes to the industrial classifications meant that two new sub-sections were edited in the services classifications: (a) information and communication – represented with only 3% in the panel but 16% in the population, and (b) professional, scientific and technical activities – represented with 9% in the panel and 14% in the population.

A.4 Methodology

The report aims to answer a set of research questions:

On resources for innovation (Appendix B)

- *What was the scale of the effect of the downturn on innovation investments?*
- *Which skills and which 'bundles of skills' are used intensively for which types of innovation?*

On drivers of innovation performance (Appendix C)

- *What was the scale of the effect of the downturn on innovation performance?*
- *How does innovation performance vary with skill intensities (UKIS Q24) and types of skills employed (UKIS Q25)?*
- *What are the impacts of skills intensity and types of skills employed on productivity and growth?*

On drivers of business performance (Appendix D)

- *What is the scale of the effect of the downturn on business performance?*
- *Did innovators do better during the recession, and what enterprise characteristics positively impact on business performance before, during and following on from the crisis?*
- *How do design skills and design investment combine to affect innovation, productivity and growth and is there a well-defined 'design led' innovation category.*

Some research questions are addressed using basic descriptive statistics of the full samples of UKIS2005, 2007, 2009 and 2011 when analysing the impact of the downturn and the full sample of UKIS2011 when elaborating on the skills usage (see Appendix B). When presenting descriptive statistics we apply survey weights that scale the samples of around 15,000 replies up to the UK enterprise population with 10 or more employees. One reply represents approximately twelve enterprises (Robson and Achur, 2011).

When we ask *what was the scale of the effect of the downturn on innovation investment, innovation performance and enterprise performance* we summarise three sets of variables taken from the surveys: (a) innovation related investments in R&D and other expenditures; (b) product and process innovations and innovative sales; (c) labour productivity and employment growth. When we ask *which skills and which 'bundles of skills' are used intensively for which types of innovation,* we describe a set of questions unique to UKIS2011 which ask if a business employed the following skills: graphic arts/layout/advertising, design of objects or services, multimedia/web design, software development/database management, engineering/applied sciences, mathematics/statistics.

The links between bundles of skills and goods, services and process innovation as well as wider or organizational innovation is explored though regression models that relate indicators to inputs, including skills to the innovation indicators. The dependent and explanatory variables are all taken from UKIS2011, that is, they are observed over the same three-year period. This analysis puts the human capital element in the context of other determinants of innovation. Innovation propensity is a binary variable represented by whether or not firms have introduced a new good, service or process and the relationship with other variables is estimated using probit models. Intensity is measured for product innovations, by the share of new and improved products (goods or services) in turnover. Here the statistical technique is Ordinary Least Squares. The independent variables used in the regressions are:

Table A.3 Independent variable names and descriptions used regressions predicting innovation performance

Variable name	*Variable description*
Design skills	Enterprise employed design-related skills
S&T skills	Enterprise employed science and technology related skills
Cooperation	Enterprise cooperated on innovation
In-house R&D	Enterprise engaged in intra-mural R&D
Machinery	Enterprise with expenditure on machinery, equipment, IT software and hardware
Design	Enterprise with expenditures on design-related activities
Market preparation	Enterprise with expenditures on market preparation
Info knowledge base	Enterprise used information from universities or research institutions
Info other businesses	Enterprise used information from other businesses: suppliers, customers or competitors
Bought-in knowledge	Enterprise bought-in R&D and other knowledge, such as licensing in a patent
Trademark	Enterprise used trademarks
Patent	Enterprise applied for a patent
Copyright	Enterprise produced material eligible for copyright
Publications	Enterprise used information in the form of scientific or technical publications

Did innovators do better during the recession, and what enterprise characteristics positively impact on business performance before, during and following on from the crisis? is addressed using predictive models. These are estimated in two steps. Firstly, we regress innovation performance before, during and following on from the economic downturn in 2008, on levels of innovation investment and an extensive set of additional explanatory variables (presented in Appendix D). Secondly, we regress enterprise performance on innovation performance and a set of explanatory variables (presented in Appendix E). In the models we use, where appropriate, different time lags between dependent and independent variables. The table below represents the estimation steps.

Figure A.1. Relationships between enterprise performance, innovation performance and innovation investments before, during and following on from the crisis

Before the crisis *t=2006*	*During the crisis* *t=2008*	*Following on from the crisis* *t=2010*
Enterprise performance and growth in 2006	Enterprise performance and growth in 2008	Enterprise performance and growth in 2010
↑	↑	↑
Innovative sales in 2006	Innovative sales in 2008	Innovative sales in 2010
↑	↑	↑
Innovation related investments and firm characteristics in 2004	Innovation related investments and firm characteristics in 2006	Innovation related investments and firm characteristics in 2008

We use three performance indicators all taken directly from the innovation surveys. These are sales per employee as a crude proxy for labour productivity, change in turnover (over a two-year period, e.g. 2008 to 2010), and change in employment (also captured over a two years).

Innovators are modelled as those reporting innovative sales. We distinguish between sales from new-to-market products and sales from new-to-firm products. Innovation investment is the total innovation related expenditures per employee. We focus, in the first instance, on the intensity variables (amount spent or share of sales generated from innovations), as opposed to the propensity variables (i.e. the likelihood of an enterprise to carry out a specific activity). A main reason for this selection is that the intensity indicators refer to single calendar years (i.e. 2010, 2008 and 2006), while the propensity variables refer to a three-year period. The issue with the propensity measures is that it is to a lesser extent possible to pinpoint down the economic downturn in 2008 because, for example, the period 2006 to 2008 refer to two years before and one year of the crisis. Moreover, the year 2008 is part of the three-year reference period for both UKIS2011 (2008 to 2010) and UKIS2009 (2006 to 2008).

The two equations might be written as follows:

Stage 1: $\text{Innovation}_{i,t} = ß_0 + ß_1\text{Investment}_{i,t-1} + ß_2 X_{i,t-1} + \varepsilon_{i,t}$

Stage 2: $\text{Performance}_{i,t} = ß_0 + ß_1\text{Innovation\_hat}_{i,t} + ß_2 X_{i,t-1} + \varepsilon_{i,t}$

Performance, innovation and investment are the variables described above (after log transformation). $X_{i,t-1}$ are additional control and explanatory variables. In stage 1, which is presented in Appendix C, these are: the size of the enterprise measured as the log of the number of employees, a skills variable, measured as the share of graduates employed by the organisation, a dummy selecting enterprises established after 1st of January 2000, a dummy variable selecting all enterprises that are part of a larger enterprise group, a dummy selecting enterprises that cooperated with other enterprises, and a dummy selecting enterprises that cooperated with universities or research institutions. We also use as an independent variable a dummy that selects enterprises that felt constrained in their innovation activities because of a lack of available finance.

We further look at the correlations between exploration and exploitation strategies and how these impact innovation performance. Exploration is measured using the average score across two items measured on a four-point likert scale: “how important were each of the following factors in your decision to innovate: (i) increase range of goods or services; (ii) entering new markets or increased market share”. Exploitation is measured using the average scores across four items: “ how important were each of the following factors in your decision to innovate: (i) improving quality of goods or services; (ii) improving flexibility for producing goods or services; (iii) increasing capacity for producing goods or services; (iv) reducing costs per unit produced.

Presented in Appendix E, we estimate Stage 2 with the predicted values for innovation, and report on the estimations with the predicted values. The estimation method is two-stage least squares. Using predicted values for innovation intensity aims to address endogeneity in the innovation variable that might arise through reverse causality, or unobserved factors such as managerial capabilities. If we use predicted values than the estimation method is 2sls, instrumental variable techniques.

$X_{i,t-1}$ are additional control and explanatory variables. In stage 2 these are log of employment, share of graduates, a dummy for firms that operate in international markets, and those that are part of a wider enterprise group, and in the case of changes in turnover the log of the level of turnover.

This analysis uses the balanced panel of 912 enterprises across all four surveys to model enterprises’ innovation intensity, performance and growth at three points in time before (2006), during (2008) and following on from the financial crisis (2010). For the analysis of the relationships between skills and economic performance indicators, set out in Annex E we use a methodology of identifying summary types of innovation that rest on the empirical evidence of complementarity between innovation inputs, linkages and outcomes, dubbed ‘mixed modes’ of innovation practices. The methodology employed to develop the innovation modes is exploratory factor analysis. The variables feeding into the analysis include what sequential approaches might term inputs into and outputs of the innovation process, e.g. in-house R&D and product innovation; activities referred to as non-technological, e.g. managerial changes or new marketing concepts; and knowledge sources. Results of the factor analyses are saved as factor scores, which form variables that allocate a value to each firm that measures whether or not an individual firm was high or low on an innovation mode. These factor scores can then be used as explanatory variables in equations relating performance to a range of innovation indicators. The factor score based indicators are close to orthogonal to each other, materially reducing the problem of multi-collinearity in the estimating the models.

A.5 Summary

This purpose of this annex is to describe the surveys, methodology and variables that are used in the report. While UKIS2011 offers a unique possibility to look into the effects of the economic downturn, and, within that period at the impact of specialized skills in design and science and technology, there are a number of data limitations. These include the high item non-response rates in the UKIS2011 and issues of comparability of UKIS2011 with previous waves of the survey. Some of these shortcomings are addressed by us analysing a sub-set of enterprises that responded to four waves of the surveys. However, the panel is not representative of the UK population, being (a) more innovative and (b) biased towards medium and large enterprises.

Annex B Resources for innovation

Annex B covers the research question: *what was the scale of the effect of the downturn on innovation inputs.* We compare, before, during and following on from the crisis, innovation related investments. It also looks at the skills usage of UK businesses. Both sections report descriptive statistics and refer to Section 2 'Resources of innovation' of the main document.

B.1 Expenditures on innovation activities

We look at results for the last four waves of the innovation surveys scaled up to the enterprise population. But, occasionally we draw on results from the panel of 912 enterprises that replied to all four waves for two reasons: firstly, the panel is the dataset set is explored further in the later section using regressions, and we want to better understand any patterns specific to the panel; and, secondly, to explore if the increase in first-time respondents linked with the larger number of item non-responses in UKIS 2011 impact on changes in innovation activities in UKIS 2011.[12]

In this section we present general trends for the UK as a whole. Economic uncertainties caused by downturns, will have an uneven impact across different types of businesses, incumbent or new, large or small, but also across industries and technologies and geographies (within the UK or via international exposure). While there might be a decline in some sectors, technologies, locations and so on, other firms might "swim against the stream and increase their investment" (as suggested in Archibugi et al.' 2013a).

We are here concerned with average trends with the aim to shed some light on the impact of the crisis on the overall economic performance of the UK. While we might not be able to predict where pockets of future growth lie, we go on to identify some characteristics of those businesses and environments which are more likely to exhibit higher innovation and business performance and growth during the crisis.

We compare the share or percentage of enterprise with a specific form of innovation related expenditures and the average amount spent on innovation across the last four waves of the innovation surveys. Innovation related expenditures, captured in the surveys, are expenditures on in-house R&D, external R&D, machinery and equipment, computer hardware and software, other external knowledge (such as licensing in a patents), training of staff related to innovation, all forms of design activities and a range of marketing activities linked to new products, and we look at

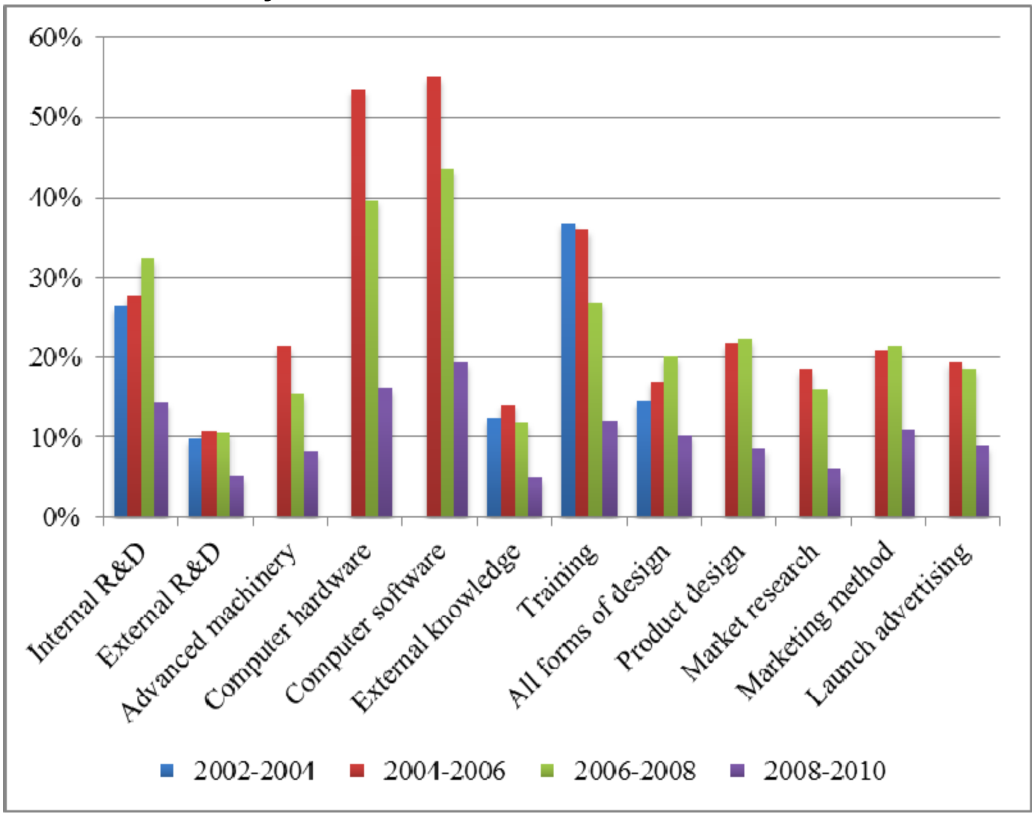
[12] Our assumption is that the 912 enterprises that replied to the last four waves of the UKIS benefitted from 'learning' in completing the questionnaires discussed in Robson and Achur (2012) and discussed in Annex A.

all of them.

We would expect that, during and following on from the recessions, enterprises on average might have been more inclined to adopt cost-saving mechanisms than in previous periods, resulting in a decline in (a) the number of enterprises with specific activities, and (b) the amount spent on each of the activities. Some of the activities, such as in-house R&D are longer-term commitments, compared with, say marketing and training activities, and, as a result, we expect different response on the extent of a possible decline and in the related time lags for different activities. Recent evidence suggests that the drop in the propensity to innovate across European enterprises active in innovation is as great as 23% (Kanerva and Hollanders, 2009). Archibugi et al. (2013a) reported an 8% decline in innovation intensity due to the crisis in UK enterprises analysing the panel between UKIS 2005, 2007 and 2009.

We first look at patterns in enterprises' propensity to invest in innovation, the share of enterprises that reported that they engaged in a specific activity. A disadvantage is that the reference periods do not refer to a specific calendar year, but to three-year periods, each with one overlapping year: 2002-2004, 2004 to 2006, 2006 to 2008 and 2008 to 2010. In Figure B.1 we report statistics based on the full UKIS samples, scaled up to the UK enterprise populations.

Figure B.1 Share of enterprises that engage in innovation related activities in 2002-2004, 2004-2006, 2006-2008 and 2008-2010, full and weighted samples, UK Innovation Survey.

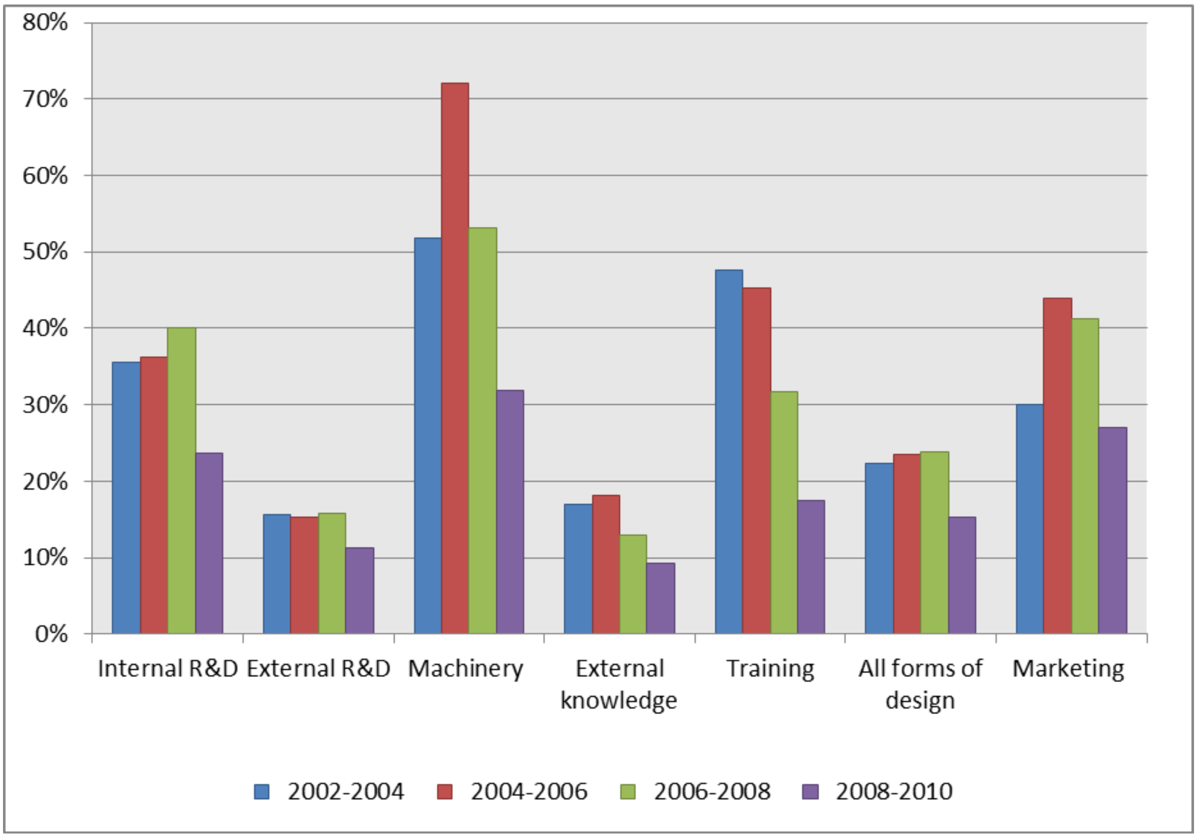


* Changes in the questionnaire design meant that UKIS 2005 with the reference period 2002-04 does not report separately on (a) advanced machinery, computer hardware and software expenditures, and (b) product design, market research, marketing method and product launch advertising.

A contraction in the number of enterprises with innovation expenditures during the economic downturn would be seen in UKIS2011, between 2008-2010. The second half of the UKIS2009 reference period may show some decline that might be associated with the early onset of the financial crisis around mid-2007. In Figure B.1 we report that the propensity to invest in innovation activities is significantly lower, on all indicators, in UKIS2011. This is true for the whole survey samples, as well as for the four-wave panel.

The panel is, on average, more innovation active, compared with the whole survey samples. We believe that the pattern reported by these 912 enterprises over the four waves of the survey, shown in Figure B.2 is likely to achieve higher comparability, albeit levels of innovation propensity are not representative of the population and results are not scaled up in an attempt to make it representative of the population. We believe that the reliability in the responses for this sub-set is greater for reasons mentioned above.

Figure B.2 Share of enterprises that engage in innovation related activities in UKIS 2005, 2007, 2009 and 2011 based on the four-wave panel



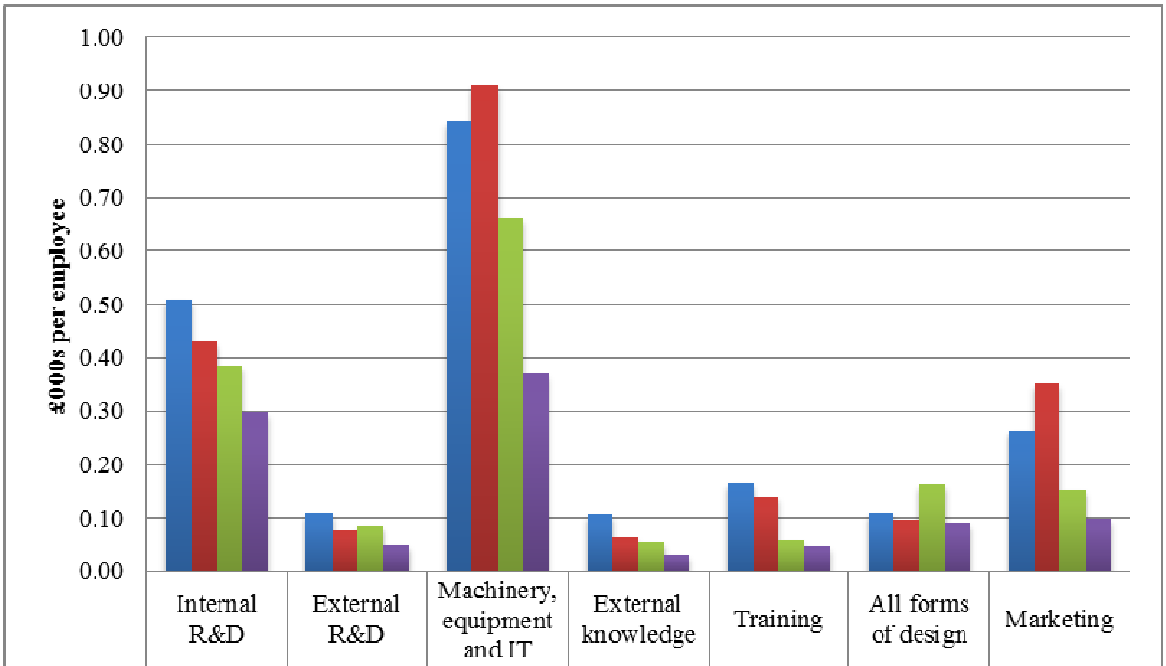
* For UKIS 2007, UKIS 2009 and UKIS 2011 ‘machinery’ contains enterprises with reported activities in three separate fields: equipment and machinery, computer hardware and software; ‘marketing’ contains enterprises with reported activities in four separate questions: product design, market research, marketing method and product launch advertising.

More extensive fluctuations are reported in connection with purchases of machinery, equipment and computer hardware and software, as well as training for innovation. Seeing the largest decline here, but also seeing a general drop in innovation propensity in UKIS2011, is perhaps in line with expectations, though the sizeable drop in the propensity to invest in R&D reported by the full samples is somewhat greater than anticipated. In-house R&D is down from 32% in UKIS2009 to 14% in UKIS2011. This would imply a large drop in innovation investment than for example the study by Kanerva and Hollanders (2009) might suggest. They report that between 23 and 29% of innovation active enterprises in Europe decreased innovation expenditures due to the crisis. We cannot be sure how much of the reported decline in the propensity to invest in innovation can be attributed to the economic downturn and how much to the changes in data collection.

As already mentioned above, the extent of the decline in innovation activity varies across the different indicators. We find almost constant (or slightly increasing) numbers of enterprises that engage in in-house, external R&D and design activities in the periods running up to 2008. But, even in these areas where more inertia or time lag might be expected, before an impact of changes in the economic environment affects the activities of enterprises, both the panel and the full samples report a significant decline in propensity.

The above discussion relates to the propensity of enterprises to engage (or not) in a specific innovation related activity. The following paragraphs look at the average intensity across the four survey periods. Expenditures are measured in £000s per employee. They relate to expenditures in the calendar years 2004, 2006, 2008 and 2010. One caveat, when looking at the following charts, is that the item non-responses on the relevant question, in particular in UKIS 2011, are high compared with item non-responses of the previous questions and of some of the innovation output measures discussed later. Findings can, therefore, only be seen as indicative of a trend.

Figure B.3 Expenditures on innovation related activities per employee, 2004, 2006, 2008 and 2010, full samples and weighted data, UK Innovation Survey

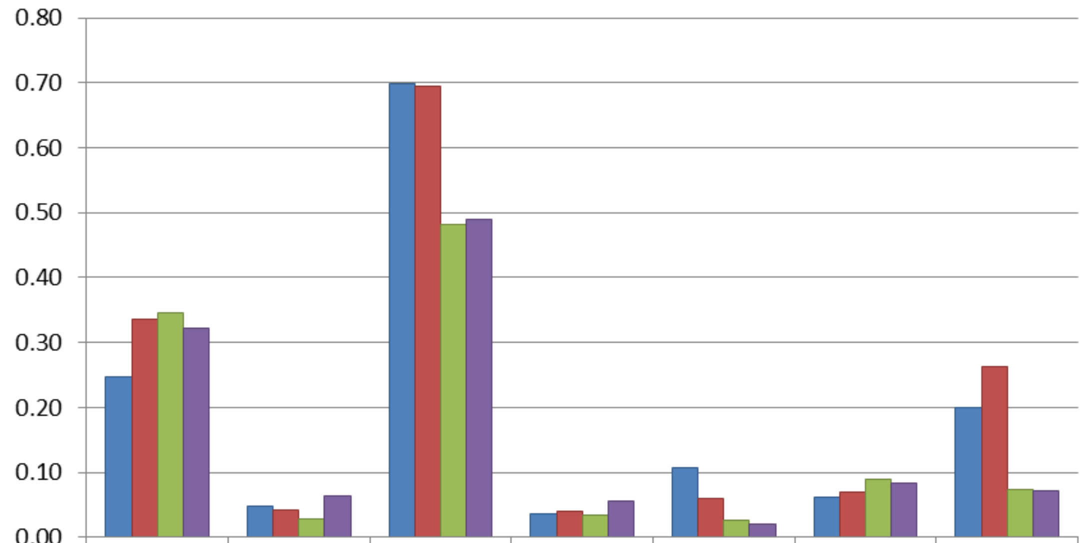


	Internal R&D	External R&D	Machinery, equipment and IT	External knowledge	Training	All forms of design	Marketing
2004	0.51	0.11	0.84	0.11	0.17	0.11	0.26
2006	0.43	0.08	0.91	0.06	0.14	0.10	0.35
2008	0.38	0.09	0.66	0.05	0.06	0.16	0.15
2010	0.30	0.05	0.37	0.03	0.05	0.09	0.10

Figure B.3 suggests a decline in the average innovation intensity between 2004 and 2010. Together with fewer enterprises carrying out such activities, the average amount invested is also lower. This is in line with previous empirical work (Archibugi et al., 2013a). Some of this downwards trend appears to pre-date the financial crisis. For example, internal R&D, external R&D and external knowledge are lower in 2006 compared with 2004 figures. The largest absolute drop in innovation intensity in 2008 and 2010 is in the amount firms spent on machinery and equipment. In 2008, at the onset of the economic turmoil, expenditures on design increased. With respect to the statistics for the year 2010, values are at lower levels than for all previous survey periods reported on.

Figure B.4 compares the pattern reported by the full and weighted CIS samples discussed above, with those of the panel – 912 enterprises that replied to four consecutive waves of the surveys and which will be analysed further in subsequent sections of the report. Data is not weighted. Results are broadly similar, albeit the average investment intensity reported by the panel is on the whole lower. Thus, while more enterprises in the panel are innovation active, on average, these innovation active enterprises are not among the highest spenders.

Figure B.4 Expenditures on innovation related activities per employee in the panel of 912 enterprises



	Internal R&D	External R&D	Machinery	External knowledge	Training	All forms of design	Marketing
2004	0.25	0.05	0.70	0.04	0.11	0.06	0.20
2006	0.34	0.04	0.70	0.04	0.06	0.07	0.26
2008	0.35	0.03	0.48	0.03	0.03	0.09	0.07
2010	0.32	0.06	0.49	0.06	0.02	0.08	0.07

While broadly in line with the patterns already reported, there are some differences with respect to specific activities. Firstly, the panel responses show an increase in internal R&D spent in 2006 and 2008 as well as a smaller decline in average in-house R&D investment in 2010, compared with the full, weighted survey replies.

Secondly, the picture for 2010 is less bleak. While the full samples reported a decline in the intensity of innovation expenditures in all areas, the panel reports growth in innovation investment in certain areas, some of which – external R&D and bought-in knowledge - above peak levels reported in 2004 or 2006. Purchases of machinery and equipment are also slightly up in 2008 (though still well behind 2004 and 2006 levels).

Thirdly, the relative decline in 2010 investments reported by the panel on the remaining activities is smaller than the variations reported in the full surveys.

On the one hand, it is likely that the earliest effects of the crisis on innovation will be seen within the area of investments for innovation, and, here, probably the quantitative expenditure figures. Any changes in innovation investments will feed into innovation outputs with a time delay. How long such a delay may be depends on many factors, including the type of investment that is reduced, the industry, the market and the enterprise size. On the other hand, the responses from UK enterprises to these expenditure questions are associated with the greatest concerns about the reliability of the data. This is specifically the case when looking at the figures reported by the full UKIS2011 sample reported in Figure B.3.

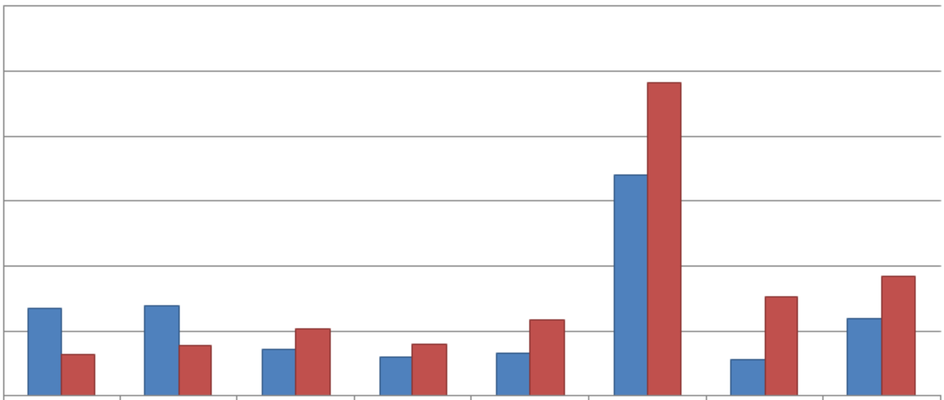
B.2 Skill for innovation

The UKIS2011 includes two types of human capital indicator: qualifications and skills. The shares of employees qualified to first degree level or above in businesses who employ graduates in two broad groups of disciplines: science and engineering and ‘other subjects’ which is an indicator of the level of qualifications in more and less technologically related disciplines available to the business and acts as a proxy, at micro-data level, for the skills level and enables investigation of the importance of this indicator in innovation.

The data on the six more specific categories of skills provides variables that enable study of the alternative hypothesis that innovation requires the application of more specialised human capital to achieve some types of innovation. This research question is also concerned with the complementary sets of human resources that may be needed for types of degrees of innovation and to improve or enable better business and economic performance. We ask *which skills and which “bundles of skills” are used intensively for which types of innovation?*

In this section we present basic bivariate patterns of the skills employed by businesses who innovate in the range of ways covered in the UKIS data. For context, we begin with the employment of graduates and specific skills for the survey respondents as a whole, before moving on to the types of skills employed by various categories of innovator. Figure B.5 shows the average share of employees that were graduates, by seven broadly defined business sectors.

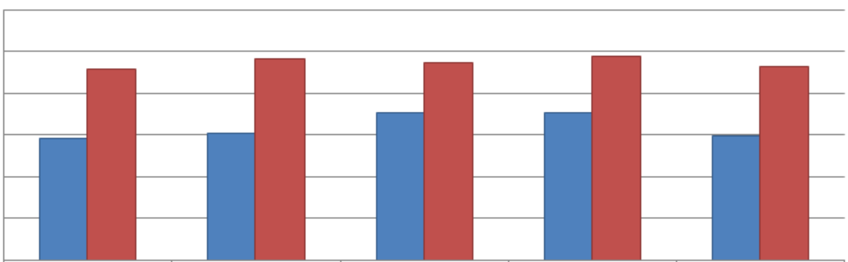
Figure B.5 Share of employees that were graduates by sector, 2008-2010, full sample and weighted data, UK Innovation Survey



	Primary	Engineering based manufacturing	Other manufacturing	Construction	Retail and Distribution	Knowledge intensive services	Other services	Total
S&T Graduates %	6.8	7	3.6	3	3.3	17.1	2.8	6
Other Graduates %	3.2	3.9	5.2	4	5.9	24.1	7.7	9.2

The knowledge intensive services sector shows the highest average share of graduates of both types of discipline, but especially non S&T. Most other sectors also have higher average shares in non S&T, although this must reflect the breadth of these disciplines. In general, services sectors report higher graduate employment proportions. Figure B.6 shows the share of graduate employment by business size, indicating relatively little size related variation.

Figure B.6 Shares of graduate employment by business size in 2010, full sample and weighted data UK Innovation Survey



	10-49	50-99	100-249	Over 250	Total
S&T Graduates %	5.8	6.1	7.0	7.0	6.0
Other Graduates %	9.2	9.6	9.5	9.7	9.2

The overall shares of businesses employing the six specific skills are summarised in Table B1. The most frequently used skill is multimedia and web design, followed closely by graphic design. The former is consistent with the importance of communications and on-line presentation and commerce in the modern economy. The latter can be considered to be the new embodiment of the traditional role of the designer of making a visualisation of the business identity as well as contributing to the appearance and usability of goods and services. The relatively high share employing software developers points to the importance of in-house as well as software purchasers. This is in-line with the results of estimates of investment in intangible assets at the aggregate level (Awano et al., 2010) which report the substantial share of own account software development in intangible investment. Interestingly a slightly higher share of firms employ object/service designers than engineering/applied science skills.

Table B.1 Share of enterprises employing specific skills, 2008-2010, full and weighted sample, UK Innovation Survey

Discipline/Skill	Share Employing %
Graphic arts/ layout/ advertising	15
Design of objects or services	9
Multimedia/web design	17
Software development/database management	14
Engineering/applied sciences	8
Mathematics/statistics	5

The more highly specialised – object and service designers, engineering and applied sciences and mathematics and statistics, are employed by far fewer businesses, and may be regarded as the more dedicated or industry specific types of skill in the survey. Software development, graphic and multimedia/web design are specialized skills for the individuals but have broader applications across industries. For example a web presence is required by most businesses.

Table B 2. Percentage of businesses employing skills, 2008-2010, full and weighted data, UK Innovation Survey

Number of employees	Graphic arts/ layout/ advertising %	Design of objects or services %	Multimedia/ web design %	Software development/ database management %	Engineering/ applied sciences %	Mathematics /statistics %
10-49	13.3	8.3	15.0	12.0	6.3	4.2
50-99	20.6	13.9	21.8	20.6	12.2	6.5
100-249	24.1	15.2	23.3	27.5	17.1	9.5
Over 250	25.9	15.4	26.1	31.8	17.1	14.1
Total	15.0	9.4	16.4	14.2	7.8	5.0

Table B 2 reports on the employment of specific skills by business size. A higher proportion of larger firms employ each type of skill, especially software developers and, relatively, science/engineering and mathematics and statistics. But the take up of these skills is widespread across the size distribution.

Innovation activities and skills

We turn next to the skills intensity of firms reporting innovation directed activities and investment**.** Firms reporting that they had activities preparing for or implementing innovations had higher skills levels as measured by the shares of graduates in their employment, shown in Table B3.

Table B.3 Percentage of businesses employing skills, 2008-2010, full and weighted data, UK Innovation Survey

	S&T Graduates	**Other Graduates**
	Mean %	Mean %
Internal R&D	15	13
Acquisition of external R&D	17	13
Advanced machinery	11	7
Computer hardware	10	11
Computer software	10	11
Acquisition of external knowledge	13	14
Training for innovative activities	12	12
All forms of design	14	12
Changes to prod or service design	12	13
Market research	13	14
Changes to marketing methods	9	12

The mean shares of graduates of S&T and other disciplines are broadly similar for most types of investment, and are considerably higher than for the survey respondents as a whole, at 6% of employment in Science and Engineering and 9% in Other Subjects. Users of advanced machinery and IT show a higher share of S&T

than other disciplines. R&D investors, especially those procuring extra-mural R&D, have the highest share of S&T graduates. The share of S&T graduates is also relatively high for those with investment in design.

From the perspective of the employment of specific skills, the position is shown in Table B 4. Those with design investment not surprisingly report high shares of employment of design skills but those with each type of innovation investment also report high propensities to employ specific skills. For most forms of investment, around 65% to 75% employ some form of S&T skill, with the highest share amongst design performers with nearly 79%. For design skills, typically between 55 and 65% report some employment with the highest share amongst design investors. So design for innovation pulls through or depends on employment of both design and S&T skills.

Table B.4 Percentages of innovation investors employing specific skills, 2008-2010, full sample and weighted data , UK Innovation Survey

	Design Skills %	S&T Skills %
Internal R&D	59.1	74.6
Acquisition of external R&D	63.6	78.2
Computer software	50.8	64.7
Acquisition of external knowledge	61.1	74.1
Training for innovative activities	52.3	68.0
All forms of design	66.8	78.8
Changes to product or service design	64.4	75.9
Market research	64.1	76.3
Changes to marketing methods	59.3	68.8
Launch advertising	56.9	65.5

R&D active enterprises are also highly likely to employ skills of both types, with those acquiring extra-mural R&D showing a higher propensity. This is consistent with the hypothesis that absorptive capacity, proxied here by skills, is necessary for the effective utilisation of externally generated knowledge for innovation.

Skills and innovation investment

Turning to expenditure on innovation activities, Table B 5. shows spending per capita for each type of innovation investment according to the employment of design or S&T skills. These data show strong complementarity between skills employment and innovation investment, which is especially marked for R&D, both internal and extra-mural, with similar magnitudes of these investments per capita for employers of both design and S&T skills. The correlation partly reflects a degree of overlap or data redundancy which might be inevitable when surveying employment as well as expenditure on innovation, since the majority of costs are employment related. It is notable that extra-mural spending per capita is higher for design skills users, consistent with the importance of absorptive capacity in order to effectively use external knowledge. But the result is also in-line with the perception of design as a link between creativity and innovation, where R&D takes part of the creativity role. That is, R&D outputs can be transformed into products by the application of design. These results indicate strongly that design capability is an important aspect of technologically based (R&D intensive) innovation, not just, as is often thought, of non-technological forms although it plays its part there also.

Interestingly, per capita spending on advanced equipment and IT is lower for those employing both skill sets, which may represent firms who rely for innovation more on advances in technology embodied in equipment and software. Spending on marketing for innovation per capita is also lower for those employing these skills, which suggests some relative specialisation in promotion and market focus, as against innovation 'push' through technical or design led change in goods, services or processes. Such 'market led' strategies of innovation were identified across a range of countries in an OECD coordinated international project (Frenz and Lambert, 2009).

Table B.5 Mean per capita expenditure on innovation activities by skills employed

	No S&T Skills	S&T Skills	No Design Skills	Design Skills
	£ k Mean	*£k Mean*	*Mean*	*£k Mean*
In-house R&D	0.26	9.11	2.07	8.82
External R&D	12.41	8.39	10.29	10.72
Machinery, equipment and IT	6.46	3.96	6.43	3.24
Other knowledge	0.04	0.44	0.06	0.53
Training	0.24	0.31	0.25	0.31
Design	0.04	1.82	0.08	2.29
Marketing	2.79	0.93	2.31	1.16

Annex C Innovation performance

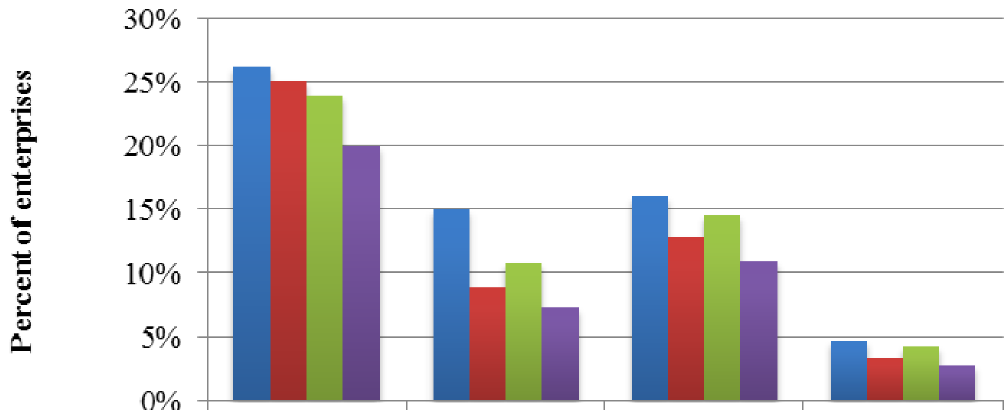
In this section we explore different indicators of innovation performance. The relationship between economic crises and innovation could go either way. Some evidence suggests that a contraction in demand spurs certain types of innovations, for example organisational changes (e.g. Alvarez et al., 2010). While Robson and Achur (2012) report on a drop in the propensity of firms to introduce new products or process between 2008 and 2010.

Annex C is the basis for Section 3 'Innovation performance' of the main report. We start our analysis by looking at the share of enterprises that had a new product (goods or services) and new production process or service delivery method in Sub-section C.1. We then look at wider innovations, consisting of new management techniques, organisational structures and marketing concepts in C.2, before turning to the share of innovative sales in Sub-section C.3.

C.1 Product and process innovation

Figures C.1 and C.2 look at the share of enterprises that introduced a new product or process based on the full, weighted surveys, and based on the panel of enterprises answering all survey occurrences, respectively.

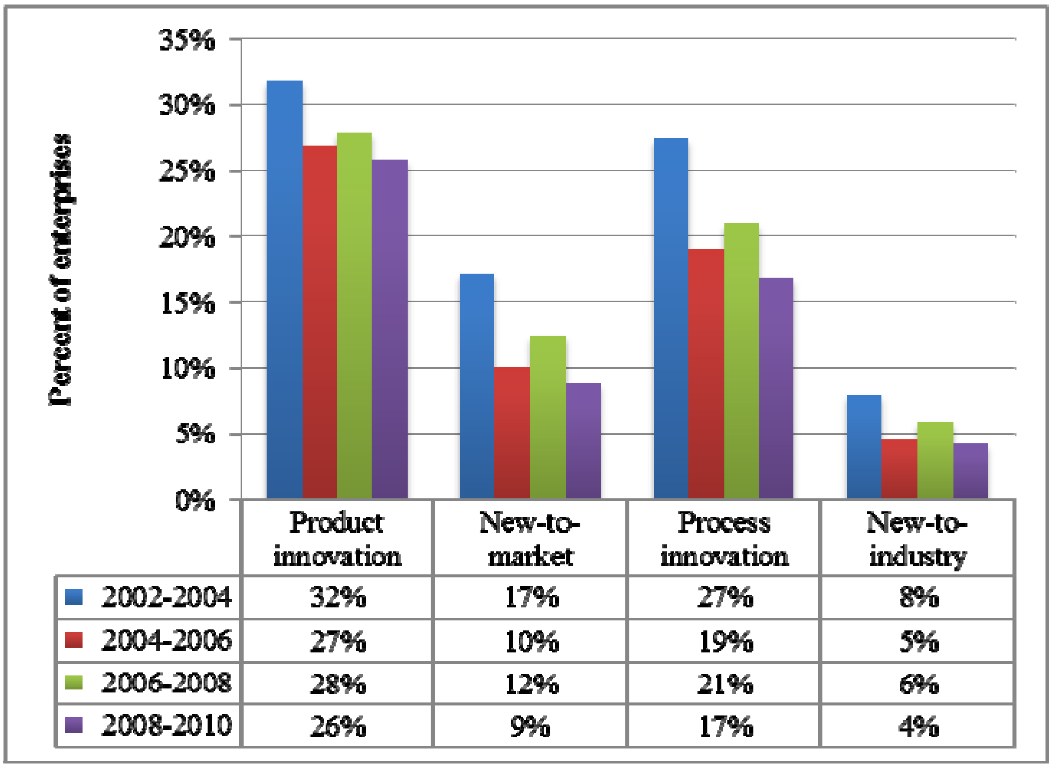
Figure C.1 Share of enterprises that introduced a new product or a new process 2002-2004, 2004-2006, 2006-2008 and 2008-2010, full and weighted samples, UK Innovation Survey.



	Product innovation	New-to-market	Process innovation	New-to-industry
2002-2004	26%	15%	16%	5%
2004-2006	25%	9%	13%	3%
2006-2008	24%	11%	15%	4%
2008-2010	20%	7%	11%	3%

The highest propensity to innovate is reported in UKIS 2005, for 2002 to 2004. The lowest propensity figures are reported in UKIS 2011 – 2008 to 2010. UKIS 2009, the period between 2006 and 2008, reports an increase in the number of enterprises that introduced a new-to-market product or process. Figure C.2 considers the panel.

Figure C.2 Share of enterprises that introduced a new product or a new process in 2002-2004, 2004-2006, 2006-2008 and 2008-2010, data is the panel of 912 enterprises that responded to all four UK Innovation Surveys



	Product innovation	New-to-market	Process innovation	New-to-industry
2002-2004	32%	17%	27%	8%
2004-2006	27%	10%	19%	5%
2006-2008	28%	12%	21%	6%
2008-2010	26%	9%	17%	4%

By and large the panel reports higher propensities to innovate. This is in line with the findings reported in Robson and Achur (2012). Both, Figures C.1 and C.2 imply that, while the share of new-to-market product innovators, process innovation and new-to-industry process innovators rose in UKIS2009 (2006 to 2008), these shares fell again in UKIS2011 (2008 to 2010) by between 2 to 4%. The drop in process innovators is marginally greater than the drop in the number of firms with new products. Sometimes, process innovations are consistent with cost saving mechanisms of the firm, providing a rationale as to why changes in production processes might increase during periods of uncertain demand (for a discussion see, for example, Kitching et al., 2009).

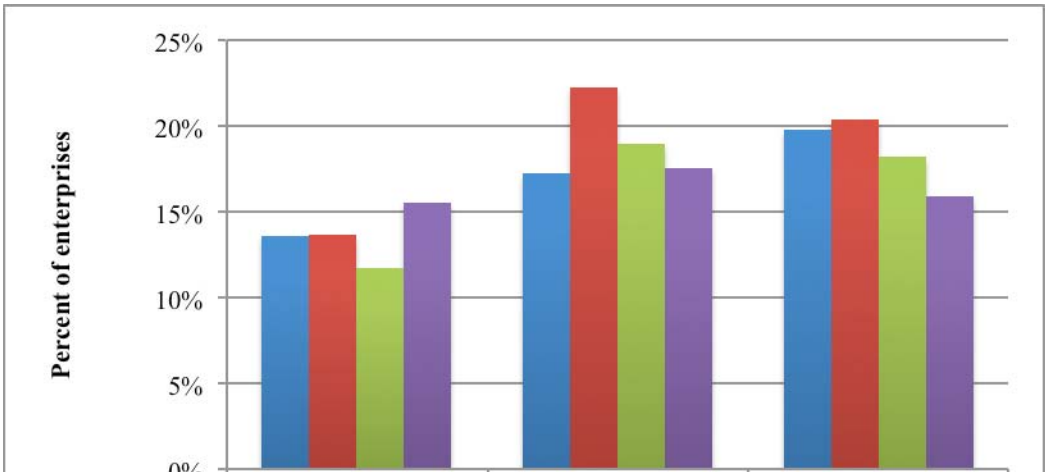
C.2 Wider innovations

The survey also collects what is frequently referred to as 'wider innovation indicators': enterprises that made changes in managerial techniques, organisational structure or marketing strategy. Enterprises faced with a decline in demand for their goods or services, or with greater uncertainties about the extent and direction of future demands, could respond to such conditions with changes to organisational structures, or increase costumer services through improved organisational processes to add further value.

The relevant question was substantially rephrased in UKIS2011 making comparisons more difficult. For 'management techniques' the original question in previous surveys referred to the "implementation of new management techniques within this business; e.g. Investors in People, Just in Time, 6 Sigma". This was changed in UKIS2011 to: "new business practices for organising procedures (i.e. supply chain management, business re-engineering, knowledge management, lean production, quality management etc.)".[13]

For 'organisational structure' the original question referred to: "implementation of major changes to your organisation structure? e.g. introduction of cross-site /teamworking" which was changed to: "new methods of organising work responsibilities and decision making (i.e. first use of a new system of employee responsibilities, team work, decentralisation, integration or de-integration of departments, education/training systems etc.). The question for 'marketing strategy' remained unchanged.

Figure C.3 Share of enterprises that introduced a new managerial technique, organisational structure or marketing strategy in 2002-2004, 2004-2006, 2006-2008 and 2008-2010, full samples and weighted data, UK Innovation Survey.



	Management technique	Organisational structure	Marketing strategy
2002-2004	14%	17%	20%
2004-2006	14%	22%	20%
2006-2008	12%	19%	18%
2008-2010	16%	18%	16%

The share of enterprises reporting new management techniques and business

[13] The changes to the wider innovation question in UKIS2011 bring the UK questionnaire in line with the EU harmonized questionnaire, which provides greater comparability with other EU countries, but for the purpose of this report, comparing across waves of UKIS, limits its usefulness.

practices grew between 2008-10. The share of enterprises that made changes to their organisational structure showed a one percent drop while two percent fewer enterprises introduced a new marketing strategy in 2008-10.

Wider forms of innovation – organisational and managerial in nature – are strongly correlated with an innovation investment indicator – purchases of ‘advanced equipment and computer hardware and software’, showing the importance of complementary between investment and business process innovation. This complementarity points to the importance for technology diffusion of ‘absorptive capacity’ in firms, in the form of the human capital and teamwork needed to make effective use of externally supplied tangible and intangible assets such as equipment and information technology. This has policy implications for example, the success of efforts in promoting the wider or faster take up of particular technologies will in part depend on this ‘absorptive capacity’ which can to a degree be measured using the skills indicators in UKIS 2011. This relationship is also an indication that innovation tends to take the form of bundles of related activities, not just single ’events‘ such as new products and processes (Battisti and Stoneman, 2010). The role of bundles or ‘modes’ of innovation in business performance is explored in Annex E.
The patterns in the panel – not graphically presented here – are similar. Overall propensity to innovate is higher – around 10 per cent. Share of enterprises with changes to management techniques is up, and share of enterprises with changes to their organisational structure and marketing strategy are down.

C.3 Innovative sales

As well as propensity, the surveys include two questions designed to measure innovation intensity - the percentage of sales in a specific calendar year that are derived from (a) new-to-market products (goods and services) and (b) from products new to the enterprise but not new to the market. We use these variables to derive a proxy for innovation intensity that is not the percentage of turnover, but the actual turnover per employee derived from (a) and (b) above. This transformation avoids any distortion that may derive from single product enterprises that may report 100% of new sales (for a discussion on the use of this indicator, see for example Frenz and Ietto-Gillies, 2009). These two indictors are later used in the regression predicting innovation performance before, during and following on from the crisis. The figures below report on the two types of innovative sales per employee based on weighted data of full samples on the 912 enterprises in the panel.

Figure C.4 Innovative sales per employee: 2004, 2006, 2008 and 2010, UK Innovation Survey.

Full and weighted samples | *Panel of 912 enterprises*

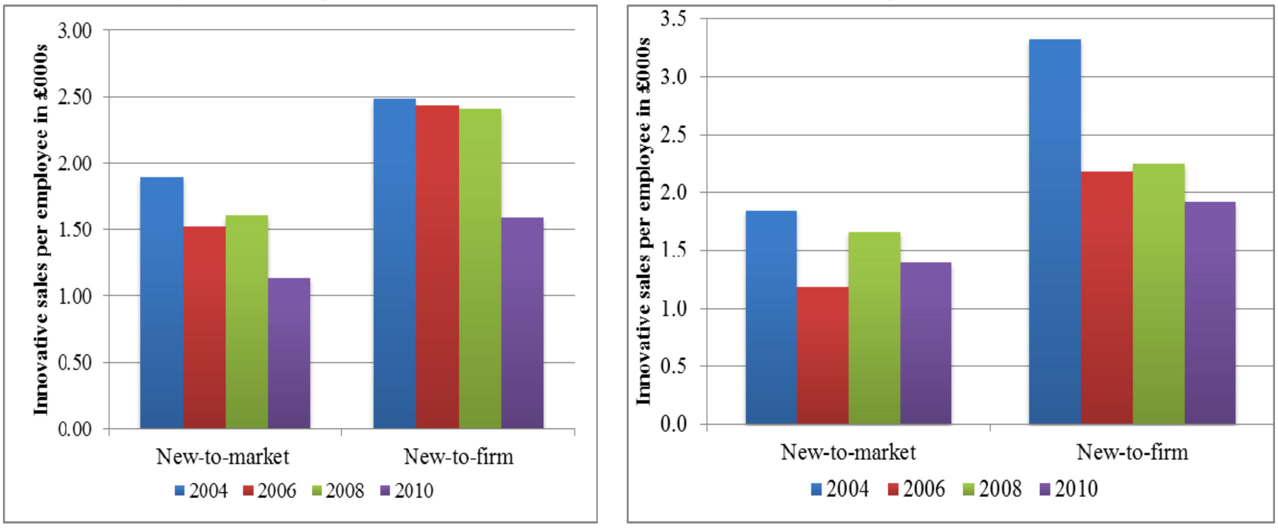


Figure C.4 reports, both the full and weighted samples and the 912 enterprises in the panel, an increase in innovation intensity from 2006 levels in 2008, and a subsequent decline in innovation intensity in 2010. This is the case for both new-to-market sales, as well as for new-to-firm sales. The 2010 decline in new-to-market sales for the panel, however, does not outweigh the increase in new-to-market sales of the pervious period and the 2010 reported figure for new-to-market sales is higher than that for 2006 (pre-crisis). In the full samples, however, innovation intensity on both measures – new-to-market and new-to-firm – in 2010 is below levels of all previous periods.

We reported a decline in innovation investments in 2008 and leading up to 2008, and Figure C.4 above is consistent with that decline leading to lower innovation intensities in 2010. These are the time lags that we use in the later section when predicting innovation performance based on different investment intensities.

Annex D Drivers of innovation performance

This Annex covers the evidence and detailed analysis that supports the Drivers of Innovation Performance section in the report. It includes first, a full account of the relationship between the various forms of innovation and the employment of the specific skills and second a systematic summary of the changes over time in innovation performance.

D.1 Skills by innovation category

We turn next to the types of skills and qualification levels employed by firms engaged in the range of types of innovation, addressing the research question: *which skills and which 'bundles of skills' are used intensively for which types of innovation.*

Table D.1 shows the shares of businesses recording employment of one of the specific skills that have one or more of the categories of innovation. Table D.2 shows the mirror image of Table D.1, the shares of innovating businesses that report employing the specific skills.

Innovators in both goods and services report the use of all types of skill. It is notable that a quarter of service innovators employ designers of objects and services, as well as the graphics and multi-media designers that might also be associated with the marketing of service innovations. The finding is consistent with the role in innovation of an emerging 'service design' specialisation in the design industry and in academic research (For a brief introduction to the field of service design see AHRC/Design Council, 2012)

Table D.1 Share of skills employing businesses that were innovators, 2008-2010, full sample and weighted data, UK Innovation Survey

Type of innovation	New or sig improved goods	New or sig improved services	Product new to market	New or sig improved processes	Process new to industry
Skill that business is employing	%	%	%	%	%
Graphic arts/layout/advertising	30.3	31.7	22.1	30.3	25.7
Design of objects or services	41.6	34.4	28.2	36.6	30.4
Multimedia/web design	28.2	32.0	21.3	30.0	25.3
Software development/database management	28.8	34.3	22.2	33.8	26.0
Engineering/applied sciences	41.0	29.0	29.8	35.2	31.9
Mathematics/statistics	32.5	34.1	27.9	34.9	33.2

Table D.2 Shares of innovators that employed a specific skill, 2008-2010, full sample and weighted data, UK Innovation Survey

Type of innovator	New or sig improved goods	New or sig improved services	New to market	New or sig improved processes
Type of skill employed	%	%	%	%
Graphic arts/layout/advertising	42.8	39.2	47.6	40.8
Design of objects or services	34.2	25.1	35.1	30.1
Multimedia/web design	43.4	42.5	49.3	43.1
Software development/database management	38.5	42.5	47.5	44.5
Engineering/applied sciences	28.8	19.1	35.3	25.5
Mathematics/statistics	14.3	14.3	20.5	15.6

A comparison of the two tables enables some light to be shed on the debate about the extent to which specialised skills use is demand led – required by innovation strategy (Table D.2), or a driver – skills enable and support more or different innovation to be attempted and implemented (Table D.1). There is some asymmetry between the share of firms employing particular skills who report innovations and the share of each innovator type employing each skill.

We first look at the shares of firms using each skill who undertake various types of innovation (Table D.1). This perspective could be a ‘capability’ interpretation - the presence of a particular skill or skill set in the enterprise enables innovation when opportunities, such as the emergence of a market occur. The main points emerging from this perspective are:

1. Object and service design and science/engineering employers show higher shares of goods innovation.
2. Services innovation shows similar proportions across all design skills but higher for employers of software developers than for other S&T skills.
3. Process innovation is most frequently achieved by employers of object and service designers while showing very similar frequency amongst users of all three S&T skills.
4. Object and service designers are more often associated with product innovations that are new to market, while engineering and applied science skills users show the higher incidence, by a small margin.
5. For object and service design and engineering and applied sciences employment are again the categories most frequently associated with new business practices,
6. For innovation in work practices, object and service design with equally software development and mathematics and statistics are the leading forms.
7. For innovation in external relations, object and service design again leads while mathematics and statistics are slightly more frequent amongst S&T skills.
8. For marketing innovation, all design skills have similar frequency while software development leads amongst S&T skills.

Another angle on the role of specific skills in innovation derives from the share of innovating businesses that employ the various skills (Table D.2). This perspective can be given a more demand-based interpretation - innovation or innovation strategies are planned and the required skills are recruited and applied to effect the plans. From this angle, the survey data indicate:

9. Amongst both goods and services innovators, around one quarter to one third employ object and service designers, but over 40% employ graphic or web/multimedia designers. Amongst S&T skills, product innovators were more likely to employ software developers, with lower shares of engineering and applied sciences (20- 28%) and mathematics and statistics (15%).
10. Higher shares of novel product innovators employed all the specific skills, with nearly 50% employing multi-media and web designers and software developers.
11. Process innovators show a similar pattern of skills employment to product innovators, with the higher shares in multimedia/web design and software development.
12. Across the categories of wider innovation, around 25 to 30% employ object and service designers with 40-45% using graphics or multimedia/web skills. Some 35 % employ software development skills, 25% engineering/applied sciences and 15% mathematics and statistics.
13. Managerial and organisational as well as product and process innovation are specific skills using activities, which throws light on one of the issues raised in

the literature about the relative importance of specific and generic skills for national innovation performance.

The question whether the demand for these specialised skills is predominantly derived from other determinants of innovation or whether their employment can drive innovation can now be considered quantitatively. This is undertaken by computing the shares of firms employing a skill (taken as an indicator of capability to drive innovation) who record each type of innovation and the shares of innovators of each type who employ that skill (taken as an indicator that specific skills are a derived demand). The ratio of these shares is an indicator of the relative importance of each role. On this interpretation, the majority of specific skills are employed through derived demand – the computed ratio is less than one. But in several instances, the capability effect is predominant (the ratio is greater than one) and this position pertains in the case of the most highly specialised skills:

- Designers of objects and services appear as drivers of innovation in goods, service and process innovation.
- Engineering and applied sciences appear as drivers of innovation in goods, services and process innovation
- Mathematics and statistics employment appears as a driver in each form of innovation.

We can conclude that the specific skills covered in the survey are major ingredients for successful innovation while the more highly specialised skills appear as original or creative resources that enable innovation.

The basic analyses of the employment of specific skills and generic/high level skills shows that innovators of each type – good and services/process and wider – are relatively skills intensive, and tend to employ a mix of skills. This confirms that a full treatment of skills and human capital for innovation more generally has been an important missing element in the micro data evidence base for innovation analysis and policy. The addition of the specific skills questions to the survey significantly enhances the range and depth of insightful analysis that the resulting micro-data permits.

Notably, the share using design skills in marketing strategy is only slightly higher than for the other practices, which shows that marketing is just one application of design. This has implications for the coverage of design in the Oslo manual and the innovation surveys guided by it. The current version of the manual, although recognizing in principle that design is a constituent of product and process innovation, suggests that, for measurement purposes, it should mainly be treated as an aspect of marketing innovation, where changes to function and use of goods and services are not involved.[14]

[14] Marketing innovation is the implementation of a new marketing method involving significant changes in product design and packaging, product placement, product promotion or pricing. Marketing innovations include significant changes in product design, in the sense of changes in product form and appearance that do not alter the product's functional or user characteristics. (Oslo Manual, paragraph 203).

The employment of skills is largely the result of demand to support innovation that has been triggered substantially by exogenous factors. But employing the most specific skills -object and service designers, engineering and applied sciences and mathematics and statistics skills provides a net capability for innovation and these can be interpreted as innovation originators.

D.2 The link between skills and innovation performance

In this section we aim to address *how innovation propensities and intensities vary with skills?* We continue first with a set of cross-tabulations on the innovation and skills variables, before estimating a set of regression models that uses as its explanatory variables the different types of skills to predict innovation propensity – whether an enterprise engages in a specific innovation activity and intensities – the share of innovative sales.

Innovation is the result of combinations of factors, with variable proportions depending on the nature of the product or process, the market and the underlying technology paradigm. These sets of complementary assets and capabilities at firms level will include skills and human resources more generally. We frame the approach to this research question in an approach to finding the role of the skills covered by the survey in the contexts of such patterns of complementarities.

The tabulations of innovation activities and outcomes against skills indicators have shown that, on a simple bivariate basis, innovation is generally highly skills using. But how far do the specialised skills covered in the survey enable or determine particular forms of innovation?

The approach to this research question therefore develops the analysis to examine the interrelationships between skills in employment and the other innovation inputs and outcomes. The further analysis includes the responses of innovation to skills, conditional upon the other innovation factors, such as activities and information flows. We proceed through modelling the relationship between innovation indicators, notably goods, services and process innovation as well as wider or organizational innovation and the employment of specialised skills, though regression models that relate indicators to inputs, including skills. The dependent and explanatory variables are all taken from UKIS2011, that is, they are observed over the same three-year period. There is, therefore, no implication of a causal relationship, but rather the equations represent patterns of linked resources and conditioning factors associated with innovations. This analysis puts the human capital element in the context of other determinants of innovation propensity and intensity. Here, propensity is a binary variable represented by whether or not firms have introduced a new good, service or process, and the relationship controlling for other innovation relevant variables is estimated using probit models. Intensity is measured by the degree of novelty of these innovations, also using probit models and, further, for product innovations, by the share of new and improved products (goods or services) in turnover. Here the statistical technique is ordinary least squares.

The main purpose of the analysis is to identify the link between skills and types of innovation, rather than to seek the 'true' model of innovation, so a fixed set of explanatory variables is deployed in each case. These are the propensities to undertake the set of innovation activities, such as R&D or knowledge acquisition, plus summary indicators of linkages in the innovation system through firms' engagement in collaboration or use of external sources of information for innovation. In this section design skills includes graphics, design of objects/services, multi-media/web design and software development. S&T skills includes science/engineering and mathematics/statistics. All variables are binary variables and measure whether or not the business engages in the activity.

The procedure involved regressing the innovation indicators in turn on a common set of explanatory variables, including dummies for industrial sector (not reported on). Only the regression coefficients and tests of their significance are shown, without overall goodness of fit tests, as it is the identification and size of the interactions between the various forms of innovation 'output' and the inputs and conditioning factors that are the objective of the analysis.

Goods innovation & skills

The most basic measure of innovation – the introduction of a new or improved physical product, is positively related to design skills, with a parameter of 0.1 and positively but not significantly related to pure S&T skills. Design skills here are highly complementary to other variables that have a strong correlation with innovation in tangible products. In particular in-house R&D, design investment and the purchase of advanced equipment and IT plus marketing investment. IPR indicators especially patenting are also significantly related to goods innovation.

Table D.1 Goods innovation and skills, 2008-2010, full sample and unweighted data, UK Innovation Survey.

Dependent variable	Goods innovation	
Independent variables	Coef.	Std. Err.
Design skills	0.104*	0.044
S&T skills	0.063	0.048
Cooperation	0.238**	0.053
In-house R&D	0.525**	0.051
Machinery	0.284**	0.046
Design	0.403**	0.050
Market preparation	0.459**	0.048
Info knowledge base	0.131*	0.057
Info other businesses	0.326**	0.054
Bought-in knowledge	0.043	0.054
Trademark	0.154*	0.067
Patent	0.535**	0.073
Copyright	0.087	0.072
Publications	0.122*	0.053

Regression method is probit. We compute robust standard errors. Regressions control for industry and enterprise size. ** p<0.01, * p<0.05, + p<0.1

Service innovation and skills

Services innovation has been less researched in the empirical literature and the new variables in the survey enable some new insights into the factors that influence the way that businesses approach services. An area of design research, not so far taken into account by innovation economists, is the characteristics and innovation role of service design. This is an emerging field of design practice and academic research that provides a theoretical framework for a revised view of how design can be important in services, (AHRC/Design Council, 2012).

In the regression model, the service innovation propensity is positively and significantly related to the use of design skills, with a parameter value of 0.16 – that is, higher than the case of goods innovation. The parameter on employment of S&T skills is insignificant and negative. The fact that the parameter on design skills is larger for services than for goods tends to confirm the importance of design in services, as advanced in the emerging research and practice area of service design. Complementary assets are again in-house R&D, equipment and IT investment and propensity to marketing investment. Design investment is not significant however – the design contribution seems to be effectively captured by the design skills variable, implying that the availability of people and their specialised knowledge and training is the prominent element in design-related services innovation. The coefficients on the IPR variables are all insignificant, reflecting the limited applicability of IPR to services. It is notable that Design Council sponsored surveys of the design industry, as well as successive waves of UKIS, report relatively low take up of design IPRs in the UK.

Table D.2 Services innovation and skills, 2008-2010, full sample and unweighted data, UK Innovation Survey.

Dependent variable	Services innovation	
Independent variables	Coef.	Std. Err.
Design skills	0.161**	0.041
S&T skills	-0.062	0.048
Cooperation	0.474**	0.050
In-house R&D	0.377**	0.049
Machinery	0.685**	0.042
Design	0.071	0.050
Market preparation	0.507**	0.044
Info knowledge base	0.102+	0.055
Info other businesses	0.421**	0.053
Bought-in knowledge	0.065	0.050
Trademark	-0.025	0.065
Patent	-0.322**	0.077
Copyright	0.064	0.069
Publications	-0.036	0.051

Regression method is probit. We compute robust standard errors. Regressions control for industry and enterprise size.
** p<0.01, * p<0.05, + p<0.1

New-to-market product innovation and skills
S&T skills are much more significant for product (goods and services) novelty, whereas design skills become non-significant. Overall, novel product innovation propensity is positively and significantly related to S&T skills, with a parameter value of 0.17, but not to design skills.

Complementary investment propensities include R&D, equipment/IT, design and marketing and information from the market place. Businesses who collaborate also have an enhanced probability of novel innovation and patenting is highly important for novel product innovators. These results imply that novel product innovation is substantially a technologically driven phenomenon, either through in-house R&D or by acquiring externally generated technical knowledge. Investment in design for innovation is though significant, further implying that design acts as the interface or interpretative stage in bringing technological changes to the market in new physical goods.

Table D.3 New-to-market product innovation, 2008-2010, full sample and unweighted data, UK Innovation Survey

Dependent variable	New-to-market product innovation	New-to-market goods innovation	New-to-market services innovation
Independent variables	Coef.	Coef.	Coef.
Design skills	0.069	0.056	0.170*
S&T skills	0.171**	0.199**	0.103
Cooperation	0.507**	0.384**	0.609**
In-house R&D	0.477**	0.425**	0.412**
Machinery	0.368**	0.368**	0.374**
Design	0.276**	0.264**	0.271**
Market preparation	0.392**	0.264**	0.374**
Info knowledge base	0.001	0.097	-0.031
Info other businesses	0.280**	0.304**	0.394**
Bought-in knowledge	0.079	0.034	0.022
Trademark	0.112+	0.161*	-0.029
Patent	0.365**	0.440**	0.071
Copyright	0.240**	0.195*	0.215*
Publications	0.135*	0.207**	-0.036

Regression method is probit. We compute robust standard errors. Regressions control for industry and enterprise size.
** p<0.01, * p<0.05, + p<0.1

Novelty in goods innovation is again positively and significantly related to S&T but not design skills, with the same set of important complementary investments as overall novel product innovation. Another design indicator – the propensity to invest in design is however significant and the effects of design in innovation strategies is picked up by this variable. Patenting is important for novel goods innovation while information from publications (scientific and technical) is significant.

In contrast to novel goods innovation, the propensity to novel services innovation is positively and significantly related to design skills with a parameter of 0.17, but not to S&T skills. In house R&D, equipment/IT, design and marketing investment are important complementary inputs. Again, no IPRs are significantly related to innovation in services. The significant role of both design indicators in novel service innovation contradicts the widespread presumption that design is largely about the final appearance of innovative physical goods.

Process innovation and skills
Process innovation propensity is supported by design skills, with a parameter of 0.18, but S&T skills are not significant. Equipment/IT, design, R&D are major complementary investments, while information from the market place is especially significant as innovation knowledge. Information from the knowledge base is also significant, as is external specialised knowledge. Collaboration is of exceptional

scale and significance in process innovation, but IPRs seem unrelated. The lack of significance of S&T skills may be related to the dominance of services in the economy, where process innovation is less likely to be technology driven but to be closer to business process changes. This interpretation may be supported by the significance of equipment and IT investment.

Table D.6 Process innovation and skills, 2008-2010, full sample and unweighted data, UK Innovation Survey

Dependent variable	Process innovation	New-to-industry process innovation
Independent variables	Coef.	Coef.
Design skills	0.182**	0.119+
S&T skills	0.008	0.078
Cooperation	0.693**	0.635**
In-house R&D	0.239**	0.303**
Machinery	0.675**	0.483**
Design	0.221**	0.207**
Market preparation	0.160**	0.212**
Info knowledge base	0.198**	0.128
Info other businesses	0.478**	0.033
Bought-in knowledge	0.119**	0.060
Trademark	0.020	-0.036
Patent	-0.364**	-0.059
Copyright	0.073	0.198*
Publications	-0.023	0.042

Regression method is probit. We compute robust standard errors. Regressions control for industry and enterprise size.
** p<0.01, * p<0.05, + p<0.1

Neither skill set is significantly related to novel process innovation propensity, which is more closely related to collaboration, equipment/IT investment and in-house R&D. Design investment, however, is significantly related to novel process innovation. IPRs are generally insignificant except for copyright, which may be in-line with the significance of design investment. Data limitations affect this finding since only around 3% of enterprises report new-to-industry process innovations in UKIS 2011, and the majority employ design and S&T skills, so that their separate roles cannot be reliably estimated.

Share of innovative sales

We turn next to innovation intensity, measured by the shares of turnover in each type of product innovation. Here the regression method is Ordinary Least Squares.

Novel product share and skills

Product innovation intensity is very significantly enabled by design skills and by S&T skills. R&D and equipment/IT are major complementary investments. Information from the market is also significant as are patenting and copyright protection. We can interpret the significance of skills here as providing the enabling resource for originality in new and improved product development.

Table D.7 Share of new-to-market products in turnover, 2010, full sample and unweighted data, UK Innovation Survey

Dependent variable	New-to-market products in turnover	
Independent variables	Coef.	Std. Err.
Design skills	1.727**	0.232
S&T skills	1.364**	0.299
Cooperation	1.250**	0.317
In-house R&D	2.186**	0.384
Machinery	1.518**	0.265
Design	0.876+	0.467
Market preparation	1.737**	0.334
Info knowledge base	0.221	0.431
Info other businesses	1.767**	0.365
Bought-in knowledge	1.093*	0.461
Trademark	1.107	0.702
Patent	4.068**	0.952
Copyright	1.816*	0.883
Publications	0.120	0.448

Regression method is OLS. We compute robust standard errors. Regressions control for industry and enterprise size.
** $p<0.01$, * $p<0.05$, + $p<0.1$

A similar pattern to overall product innovation intensity applies in the case of goods innovation intensity. Design and S&T skills are particularly significant and with larger coefficients than other variables, which is not the case for most of the equations.

Table D.8 Share of novel goods in turnover, 2010, full sample and unweighted data, UK Innovation Survey.

Dependent variable	Share of turnover in new-to-market goods	
Independent variables	Coef.	Std. Err.
Design skills	1.880**	0.196
S&T skills	1.661**	0.277
Cooperation	0.899**	0.298
In-house R&D	1.127**	0.330
Machinery	1.394**	0.245
Design	1.315**	0.488
Market preparation	0.984**	0.315
Info knowledge base	-0.025	0.431
Info other businesses	1.691**	0.339
Bought-in knowledge	0.859+	0.503
Trademark	1.157	0.739
Patent	3.153**	0.989
Copyright	1.108	1.022
Publications	0.263	0.481

Regression method is probit. We compute robust standard errors. Regressions control for industry and enterprise size.
** p<0.01, * p<0.05, + p<0.1

Employment of design skills is particularly strongly related to services innovation intensity, while S&T skills are also positively and significantly related. Equipment/IT and marketing spending are especially important complementary inputs. This equation again demonstrates that design skills have a major role in services innovation while design investment is not significant. Again, novelty in innovation is significantly attributable to the employment of specialised skills.

Table D.9 Novel services share of turnover, 2010, full sample and unweighted data, UK Innovation Survey

Dependent variable	Share of turnover in new-to-market services	
Independent variables	Coef.	Std.Err
Design skills	2.154**	0.180
S&T skills	0.571**	0.214
Cooperation	0.948**	0.272
In-house R&D	1.407**	0.347
Machinery	1.273**	0.215
Design	0.109	0.445
Market preparation	1.589**	0.282
Info knowledge base	0.040	0.341
Info other businesses	1.634**	0.327
Bought-in knowledge	0.205	0.398
Trademark	0.520	0.595
Patent	1.426	0.999
Copyright	0.777	0.834
Publications	-0.386	0.350

Regression method is OLS. We compute robust standard errors. Regressions control for industry and enterprise size.
** p<0.01, * p<0.05, + p<0.1

Wider innovation

The types of innovation thought of as 'wider' or management/organisational have assumed increasing importance in innovation studies in recent years, as there is some evidence that they can be as effective in enhancing performance as the 'classic' forms of product and process change. We report here on the relationship between the wider or organisational forms of innovation and skills indicators.

Table D.10 New Business Practices and skills, UKIS2011 full and weighted sample

Dependent variable	New business practices	
Independent variables	Coef.	Std. Err.
Design skills	0.282**	0.037
S&T skills	0.127**	0.043
Cooperation	0.191**	0.047
In-house R&D	0.286**	0.047
Machinery	0.720**	0.038
Design	0.144**	0.049
Market preparation	0.375**	0.042
Info knowledge base	0.131*	0.053
Info other businesses	0.271**	0.048
Bought-in knowledge	0.210**	0.050
Trademark	0.081	0.067
Patent	-0.272**	0.076
Copyright	-0.004	0.073
Publications	0.015	0.050

Regression method is probit. We compute robust standard errors. Regressions control for industry and enterprise size.
** p<0.01, * p<0.05, + p<0.1

Innovation in Business Practices is strongly correlated with the use of design skills and, to a lesser extent, with the employment of S&T skills. The most significant complementary investment is in new equipment and IT. This result is consistent with the findings of the economics literature that innovation in business practices, with support from deploying modernised IT, can have major impacts on the efficiency of an organization. Design investment is also significant.

A very similar pattern pertains in the case of changes to work organisation, with both types of skill significant, with complementary equipment/IT investment and with use of information from scientific and trade publications. For this form of wider innovation, scientific and technical publications are also significant, implying the importance of dissemination of organisational practices in codified form.

Table D.11 New methods of work organisation and skills, 2008-2010, full sample and unweighted data, UK Innovation Survey

Dependent variable	New methods of work organisation	
Independent variables	Coef.	Std. Err.
Design skills	0.315**	0.036
S&T skills	0.115**	0.043
Cooperation	0.219**	0.047
In-house R&D	0.205**	0.048
Machinery	0.791**	0.037
Design	0.062	0.049
Market preparation	0.419**	0.041
Info knowledge base	0.005	0.053
Info other businesses	0.155**	0.048
Bought-in knowledge	0.203**	0.050
Trademark	-0.123+	0.066
Patent	-0.352**	0.075
Copyright	-0.013	0.071
Publications	0.127*	0.049

Regression method is probit. We compute robust standard errors. Regressions control for industry and enterprise size.
** p<0.01, * p<0.05, + p<0.1

Firms reporting this form of wider innovation also employ design and S&T skills, with spending on marketing for innovation a major complementary investment, while equipment/IT spending are also significant.

Table D.12 New methods of organising external relations and skills, 2008-2010, full sample and unweighted data, UK Innovation Survey

Dependent variable	New methods of organising external relations	
Independent variables	Coef.	Std. Err.
Design skills	0.218**	0.045
S&T skills	0.142**	0.049
Cooperation	0.186**	0.055
In-house R&D	0.135*	0.054
Machinery	0.403**	0.047
Design	0.149**	0.051
Market preparation	0.551**	0.048
Info knowledge base	0.179**	0.059
Info other businesses	0.082	0.056
Bought-in knowledge	0.289**	0.051
Trademark	0.131*	0.067
Patent	-0.104	0.075
Copyright	-0.081	0.073
Publications	-0.026	0.054

Regression method is probit. We compute robust standard errors. Regressions control for industry and enterprise size.
** p<0.01, * p<0.05, + p<0.1

Innovation in marketing strategy is strongly related to the employment of design skills, but not to the employment of S&T skills. The link with design skills is consistent with findings from Design Council sponsored surveys of design users, which showed that, while design is employed as part of R&D and new product development by up to 40% of businesses, around 70% deploy design capability in their marketing efforts. That is, marketing is a main but not the only significant application of design.

Table D.13 New marketing concept or strategy and skills, 2008-2010, full unweighted data, UK Innovation Survey

Dependent variable	New Marketing Concept or Strategy	
Independent variables	Coef.	Std. Err.
Design skills	0.384**	0.039
S&T skills	-0.071	0.047
Cooperation	0.098+	0.050
In-house R&D	0.115*	0.051
Machinery	0.449**	0.041
Design	0.035	0.051
Market preparation	1.213**	0.042
Info knowledge base	-0.016	0.056
Info other businesses	0.253**	0.050
Bought-in knowledge	0.162**	0.051
Trademark	0.075	0.065
Patent	-0.290**	0.077
Copyright	0.090	0.070
Publications	0.029	0.052

Regression method is probit. We compute robust standard errors. Regressions control for industry and enterprise size.
** p<0.01, * p<0.05, + p<0.1

D.3 Drivers of innovation performance over time

The report so far showed, e.g. in Annex B, that fewer enterprises invested in innovation related activities from 2008 onwards, and that intensity of investment was lower. The descriptive patterns also suggest that innovation outputs, the introduction of new products and processes, and sales from new products were lower in 2010, than in previous periods. This section seeks to uncover possible differences in the characteristics of enterprises that are innovative at different points in time, and to see if different businesses drive innovation during and following on from the crisis, compared to before the crisis.

Table D.14 presents results of OLS regressions at three points in time explaining new-to-market (novel) sales per employee. New-to-market is the more demanding indicator, compared with new-to-firm sales, to which we later turn. These regressions also form the first stage of a two-step estimation process (two stage least squares) with which we predict enterprise performance in Appendix E.

Before the crisis, innovation intensity is measured in 2006, and the explanatory variables, including total innovation related investments, are captured in 2004, to allow for some time before investment levels translate into successful innovations.

During the crisis, we measure new-to-market sales in 2008 and the explanatory variables in 2006, and following on from the crisis, we look at innovative sales in 2010 with the explanatory variables, measured in 2008 (during the crisis).

Enterprises with exploratory strategies are more likely to report high levels of new-to-market sales before, during and following on from the crisis.

Table D.14 New-to-market sales per employee before (2006), during (2008) and following on from the crisis (2010), UK Innovation Survey

Dependent variables	New-to-market sales per employee t		
Independent variables	2006	2008	2010
Innovation investment t-1	0.11**	0.07+	0.15**
	(0.034)	(0.042)	(0.050)
Employment t-1	0.04*	0.01	0.03
	(0.018)	(0.025)	(0.030)
Newly established	0.08	0.03	-0.15+
	(0.082)	(0.086)	(0.081)
Group belonging	-0.07	-0.07	0.03
	(0.054)	(0.053)	(0.054)
International market t-1	0.17*	0.08	0.12
	(0.070)	(0.073)	(0.076)
Cooperation with other business t-1	-0.08	0.14	0.01
	(0.124)	(0.193)	(0.105)
Cooperation with research institute t-1	0.11	-0.06	0.04
	(0.147)	(0.248)	(0.153)
Explorative strategies t-1	0.13**	0.15+	0.16+
	(0.046)	(0.083)	(0.093)
Exploitative strategies t-1	-0.02	0.08	0.03
	(0.049)	(0.094)	(0.049)
Finance t-1	-0.17**	0.05	0.08
	(0.057)	(0.092)	(0.079)
Skills t-1	0.17+	-0.01	-0.11+
	(0.085)	(0.078)	(0.059)
Industry dummies	Included	Included	Included
Constant	-0.36*	-0.05	-0.29
	(0.170)	(0.249)	(0.251)
Observations	690	684	561
R-squared	0.182	0.216	0.182
F-statistic	3.65**	3.29**	2.44**

Regression method OLS. Regression coefficients with robust standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Table D.14 shows that total innovation investment is positively correlated with new-to-market sales per employee in all three years. The coefficient is highest in 2010, with those enterprises that report higher innovation investment figures in 2008 also reporting higher new-to-market sales.

Before the crisis the following enterprise characteristics correlate with new-to-market sales: enterprises that follow exploratory strategies (seeking out new markets and products), those that operate in international markets, are larger in size and employ a higher share of graduates. This might lean towards the notion of technological accumulation, with highly innovative and established firms playing a dominant role. A lack of available finance for innovation has a negative association with new-to-market sales.

We do not find all the same positive and significant correlations when explaining new-to-market innovation intensity in 2008. In fact, fewer of the predictor variables show a significant correlation with new-to-market sales. But, there is some indication that, next to innovation investments, exploratory strategies matter during the crisis.

Following on from the crisis – innovation intensity in 2010 – a pattern more closely associated with accumulation emerges, with those enterprises that are longer established, and with in-house R&D facilities.

Table D.15 looks at the characteristics of those enterprises with high levels of new-to-firm sales, in other words, sales from goods and services which may have previously been available in the market, but which are new to the reporting enterprise.

Table D.15 New-to-firm sales per employee before (2006), during (2008) and following on from the crisis (2010)

Dependent variables	New-to-firm sales per employee t		
Independent variables	2006	2008	2010
Innovation investment t-1	0.21**	0.19**	0.09+
	(0.045)	(0.053)	(0.055)
Employment t-1	0.04	0.03	-0.01
	(0.026)	(0.024)	(0.028)
Newly established	0.17	0.05	0.19
	(0.110)	(0.101)	(0.143)
Group belonging	-0.06	-0.03	0.11
	(0.061)	(0.063)	(0.071)
International market t-1	0.14+	0.16*	0.07
	(0.073)	(0.082)	(0.069)
Cooperation with other business t-1	-0.15	0.50**	0.04
	(0.142)	(0.177)	(0.122)
Cooperation with research institute t-1	0.20	-0.23	0.09
	(0.177)	(0.227)	(0.168)
Explorative strategies t-1	0.11+	0.10	0.08
	(0.057)	(0.075)	(0.103)
Exploitative strategies t-1	0.00	0.04	0.11+
	(0.062)	(0.085)	(0.059)
Finance t-1	-0.02	0.03	-0.02
	(0.086)	(0.102)	(0.093)
Skills t-1	0.31*	0.01	0.16
	(0.144)	(0.097)	(0.109)
Industry dummies	Included	Included	Included
Constant	-0.14	-0.20	0.29
	(0.231)	(0.253)	(0.267)
Observations	696	760	564
R-squared	0.210	0.188	0.184
F-statistic	5.16**	5.16**	3.20**

Regression method OLS. Regression coefficients with robust standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Innovation investments are positively correlated with new-to-firm sales (as previously to new-to-market sales), before, during and following on from the crisis (although following on from the crisis both the coefficient size and significance are lower). Enterprise size is not positively correlated with new-to-firm sales, and, although being established after 1st of January 2000 is not statistically significantly correlated with new-to-firm sales, the coefficient following on from the crisis is positive – it was negative in the case of new-to-market sales – and has the largest effect size across the regression models.

Further, we observe a shift from exploratory strategies explaining new-to-firm sales in 2006 towards exploitative strategies explaining new-to-firm sales in 2010. Exploratory strategies are those aimed at finding or opening up new markets and developing new products, while exploitation strategies aim at improvements to existing products and cost cutting in the production or delivery. Finally, new-to-firm sales in 2008, during the crisis, are positively correlated with collaborative innovation projects, where partners are other enterprises.

Tables D.14 and D.15 showed that the coefficient for total innovation related investment being positively correlated with innovation performance, whether new-to-market or new-to-firm. In Table D.16 we present regressions with expenditures in individual areas: in-house R&D, bought-in R&D and so on.

Table D.16 Innovation investments broken down into individual activities. New-to-firm sales

Dependent variables / *Independent variables*	New-to-firm sales per employee t 2006	2008	2010
In-house R&D investment t-1	0.25+	0.38**	0.34*
	(0.139)	(0.146)	(0.138)
Bought-in R&D t-1	-0.62*	-0.02	-0.63**
	(0.275)	(0.355)	(0.193)
Machinery and equipment t-1	0.08	-0.09	-0.06
	(0.064)	(0.065)	(0.051)
Bought-in other knowledge t-1	0.88**	-0.26	0.58
	(0.266)	(0.173)	(0.417)
Innovation related training t-1	-0.30+	0.38	0.13
	(0.160)	(0.318)	(0.197)
All forms of design t-1	0.54*	0.72**	-0.09
	(0.243)	(0.192)	(0.143)
Marketing of new products t-1	-0.10	-0.15+	0.10
	(0.103)	(0.082)	(0.111)
Employment t-1	0.01	0.01	-0.02
	(0.025)	(0.025)	(0.028)
Newly established	0.19	0.13	0.24+
	(0.117)	(0.110)	(0.135)
Group belonging	-0.07	-0.06	0.10
	(0.062)	(0.069)	(0.071)
International market t-1	0.16*	0.27**	0.05
	(0.076)	(0.086)	(0.068)
Cooperation with other business t-1	-0.14	0.25	0.08
	(0.145)	(0.173)	(0.120)
Cooperation with research institute t-1	0.23	-0.04	0.07
	(0.178)	(0.235)	(0.162)
Explorative strategies t-1	0.09	0.11	0.03
	(0.056)	(0.091)	(0.104)
Exploitative strategies t-1	0.04	0.05	0.14*
	(0.060)	(0.096)	(0.060)
Finance t-1	-0.06	-0.02	-0.02
	(0.084)	(0.112)	(0.090)
Skills t-1	0.37**	0.02	0.12
	(0.137)	(0.102)	(0.110)
Industry dummies	Included	Included	Included
Constant	0.20	0.12	0.44+
	(0.225)	(0.227)	(0.253)
Observations	717	648	582
R-squared	0.244	0.215	0.214
F-statistic	5.799	4.170	2.908

Regression method OLS. Regression coefficients with robust standard errors in parentheses
** p<0.01, * p<0.05, + p<0.1

Breaking down the total innovation related investments, we find that in-house R&D and design expenditures, better predict new-to-firm sales than any of the remaining investment types. Bought-in R&D shows negative correlations.

Annex E Drivers of business performance

In this Annex we provide the more detailed data and analyses underpinning the Drivers of Business Performance section of the report, including drivers of performance over time and the relationship between skills and business performance over the survey period itself, that latter using a methodology of estimating ‘mixed modes’ of innovation.

E.1 Drivers of business performance over time

This section seeks to address if enterprises with high innovative sales fared better during and following on from the 2008 downturn. We proxy performance as sales per employee (labour productivity) and change in sales and employment before, during and following on from the crisis. Tables E.1 and 2 below reports the regressions. Innovative sales per employee are measured in the same year as sales per employee and growth. We distinguish between new-to-firm and new-to-market sales. The remaining predictive variables are measured in the previous survey reference year.

Table E.1 Sales per employee and new-to-firm sales before, during and following on from the crisis

Dependent variables	Sales per employee t		
Independent variables	2006	2008	2010
New-to-firm sales per employee t	0.50**	0.18*	0.21+
	(0.151)	(0.092)	(0.121)
Skills t-1	0.28*	0.55**	0.45**
	(0.130)	(0.079)	(0.093)
International market t-1	0.34**	0.42**	0.37**
	(0.087)	(0.079)	(0.094)
Group belonging	0.32**	0.25**	0.34**
	(0.069)	(0.064)	(0.085)
Employment t-1	-0.05+	-0.08**	-0.11**
	(0.028)	(0.028)	(0.036)
Industry dummies	Included	Included	Included
Constant	4.13**	4.46**	4.54**
	(0.208)	(0.206)	(0.280)
Observations	634	634	406
R-squared	0.456	0.472	0.433
Chi-squared	631.9	570.2	318.3

Regression method 2SLS. Regression coefficients with robust standard errors in parentheses. New-to-firm sales are predicted values using the following independent variables: innovation investment t-1, employment t-1, newly established, group belonging, international market t-1, cooperation with other businesses t-1, cooperation with research institutes t-1, explorative strategies t-1, exploitative strategies t-1, finance t-1, and skills t-1 (see Table 1 of the main report for the stage 1 equation).
** $p<0.01$, * $p<0.05$, + $p<0.1$

We comment, in particular, on the coefficients for innovation performance and for skills. Innovative sales per employee are positively correlated with sales per employee in all three time periods. In other words, enterprises with higher innovative sales also performed better in 2006, 2008 and 2010. Specifically, the pre-crisis relationship is strong. This leads us to suggest that, while highly innovative firms fare better during the crisis, the benefits that they can gain from innovation is greater in more stable economic conditions of 2006.

Further, we see that the share of graduates is positively correlated with sales per employee, and the size effect is greater during the crisis and following on from the crisis.

The correlation between new-to-market sales and productivity (sales per employee), see Table E.2, is not significant during the crisis in 2008, and again significant in 2010.

Table E.2 Sales per employee and new-to-market sales before, during and following on from the crisis

Dependent variables	Sales per employee t		
Independent variables	2006	2008	2010
New-to-market sales per employee t	0.53**	0.14	0.30*
	(0.174)	(0.112)	(0.142)
Skills t-1	0.32**	0.57**	0.47**
	(0.119)	(0.085)	(0.093)
International market t-1	0.36**	0.48**	0.34**
	(0.090)	(0.084)	(0.099)
Group belonging	0.35**	0.26**	0.36**
	(0.069)	(0.067)	(0.083)
Employment t-1	-0.05+	-0.04	-0.11**
	(0.029)	(0.029)	(0.036)
Industry dummies	Included	Included	Included
Constant	4.31**	4.34**	4.59**
	(0.205)	(0.219)	(0.273)
Observations	626	565	404
R-squared	0.477	0.479	0.417
Chi-squared	647.0**	525.3**	307.9**

Regression method 2SLS. Regression coefficients with robust standard errors in parentheses. New-to-market sales are predicted values using the following independent variables: innovation investment t-1, employment t-1, newly established, group belonging, international market t-1, cooperation with other businesses t-1, cooperation with research institutes t-1, explorative strategies t-1, exploitative strategies t-1, finance t-1, and skills t-1.
** p<0.01, * p<0.05, + p<0.1

Tables E.3 and 4 look at the impact of innovation performance on change in turnover.

Table E.3 Change in turnover and new-to-firm sales before, during and following on from the crisis

Dependent variables	Change in turnover t		
Independent variables	2006	2008	2010
New-to-firm sales per employee t	0.32**	0.04	0.07
	(0.124)	(0.071)	(0.086)
Skills t-1	0.24*	0.16**	0.03
	(0.107)	(0.058)	(0.064)
International market t-1	-0.05	0.11*	-0.02
	(0.077)	(0.057)	(0.062)
Group belonging	0.21**	0.10*	0.03
	(0.065)	(0.047)	(0.056)
Employment t-1	0.29**	0.16**	0.05
	(0.033)	(0.029)	(0.035)
Turnover t-1	-0.40**	-0.25**	-0.03
	(0.028)	(0.025)	(0.032)
Industry dummies	Included	Included	Included
Constant	2.32**	1.72**	0.10
	(0.244)	(0.187)	(0.241)
Observations	686	696	467
R-squared	0.195	0.167	0.040
Chi-squared	247.0	141.3	26.62

As per Table E.1

Table E.4 Change in turnover and new-to-market sales before, during and following on from the crisis

Dependent variables	Change in turnover t		
Independent variables	2006	2008	2010
New-to-market sales per employee t	0.32*	0.05	0.13
	(0.162)	(0.083)	(0.096)
Skills t-1	0.36**	0.12+	0.03
	(0.100)	(0.064)	(0.062)
International market t-1	-0.07	0.14*	-0.03
	(0.078)	(0.062)	(0.064)
Group belonging	0.22**	0.11*	0.03
	(0.064)	(0.051)	(0.054)
Employment t-1	0.27**	0.17**	0.05
	(0.032)	(0.031)	(0.035)
Turnover t-1	-0.37**	-0.26**	-0.03
	(0.027)	(0.026)	(0.032)
Industry dummies	Included	Included	Included
Constant	2.27**	1.72**	0.11
	(0.238)	(0.200)	(0.239)
Observations	681	620	464
R-squared	0.208	0.170	0.051
Chi-squared	222.7	131.1	31.01

As per Table E.2

New-to-firm and new-to-market sales predict growth in turnover before the crisis but are not positively correlated during and following on from the crisis. Differences in demand conditions, are likely to play the crucial role here. Skills – measured as the share of graduates among employees – shows some positive impact on turnover growth. The following two tables – E.5 and 6 – look at changes in employment.

Table E.5 Change in employment and new-to-firm sales before, during and following on from the crisis

Dependent variables	Change in employment t		
Independent variables	2006	2008	2010
New-to-firm sales per employee t	0.22*	0.15*	0.10
	(0.108)	(0.067)	(0.094)
Skills t-1	-0.22*	-0.02	-0.05
	(0.092)	(0.055)	(0.069)
International market t-1	-0.23**	-0.01	-0.00
	(0.066)	(0.054)	(0.067)
Group belonging	0.16**	0.03	0.01
	(0.054)	(0.044)	(0.060)
Employment t-1	-0.23**	-0.12**	-0.13**
	(0.022)	(0.019)	(0.025)
Industry dummies	Included	Included	Included
Constant	1.28**	0.66**	0.70**
	(0.166)	(0.142)	(0.198)
Observations	694	697	469
R-squared	0.156	0.027	0.062
Chi-squared	192.0	56.86	41.36

As per Table E.1

Table E.6 Change in employment and new-to-firm sales before, during and following on from the crisis

Dependent variables	Change in employment t		
Independent variables	2006	2008	2010
New-to-market sales per employee t	0.31*	0.15+	0.08
	(0.148)	(0.080)	(0.105)
Skills t-1	-0.12	-0.01	-0.01
	(0.090)	(0.059)	(0.064)
International market t-1	-0.25**	-0.00	-0.02
	(0.070)	(0.058)	(0.069)
Group belonging	0.16**	0.04	0.02
	(0.055)	(0.047)	(0.058)
Employment t-1	-0.24**	-0.12**	-0.14**
	(0.023)	(0.020)	(0.025)
Industry dummies	Included	Included	Included
Constant	1.42**	0.70**	0.82**
	(0.164)	(0.153)	(0.186)
Observations	688	621	466
R-squared	0.170	0.035	0.087
Chi-squared	201.5	57.16	47.74

As per Table E.2

As before in the case of turnover, new-to-firm and new-to-market sales show a positive and significant relationship with employment growth in 2006 (before the crisis). The coefficients remain significant during the crisis, showing better growth outcomes in 2008 are associated with innovation performance. In 2010, following on from the crisis the coefficients remain positive, but they are smaller and not significant. Generally, the regression models and their overall explanatory power for 2010 are low, suggesting that innovation intensity is only one part of the explanation for changes in sales and employment over the period 2008 to 2010.

E.2 Drivers of business performance: skills

We next look at the question: *what are the impacts of skills intensity and types of skills employed on productivity and growth?* A key use of innovation data is to establish how far innovation in its various forms can generate economic benefits, for example though the external benefits or spillovers to other agents or through promoting productivity and growth in the economy. In the models presented, human capital and skills may have an effect on performance directly or via their role in different types of innovation.

For the analysis of the relationships between skills and economic performance indicators, we use a methodology of identifying summary types of innovation that rest on the empirical evidence of complementarity between innovation inputs, linkages and outcomes. This methodology has been developed from earlier work under OECD auspices and generates a type of model, well suited to explore how skills indicators fit into the innovation systems context. The typology of innovation is dubbed ‘mixed modes’ of innovation practices, which can be conceived also as strategic orientations or styles of innovation, derived from many variables taken from UKIS. Modes can also be thought of as the underlying process, or latent variables of innovation, a bundle of activities undertaken together by firms, and whose working out in practice generates well known indicators such as new product innovations, R&D spending and accessing external information, that are the partial indicators gathered from the innovation survey itself.

The methodology employed to develop the innovation modes is exploratory factor analysis. Since innovation survey data have been widely available to researchers, this methodology has become well established (e.g. Battisti and Stoneman 2010, Frenz and Lambert, 2009, Leiponen and Drejer 2007). The variables feeding into the analysis include what sequential approaches might term inputs into and outputs of the innovation process, e.g. in-house R&D and product innovation; activities referred to as non-technological, e.g. managerial changes or new marketing concepts; and knowledge sources, which might be internal like R&D, acquired from external sources, such as universities, or generated in collaboration with others. Results of the factor analyses are saved as factor scores. These factor scores form variables that allocate a value to each firm that measures whether or not an individual firm was high or low on an innovation mode. These factor scores can then be used as explanatory variables in equations relating performance to a range of innovation indicators. The factor score based indicators are close to orthogonal to each other, materially reducing the problem of multi-collinearity in the estimating the models.

The modes obtained from the UKIS 2009 (Frenz and Lambert, 2012) are:

1. Investing in intangibles
2. Technology with IP innovating
3. Using codified knowledge
4. Wider (managerial) innovating
5. Market-led innovating
6. External process modernising.

These modes have been applied as explanatory variables in equations for business performance.

Table E.7 Regression model of turnover growth and modes, 2006- 2008, full samples and unweighted data, UK Innovation Survey

	Change in turnover Modes measured with no time lag[a]	Change in turnover Modes measured with a two year lag[b]
IP/techn. innovating	0.11	0.10
	(0.03)**	(0.03)**
Investing in intangibles	0.04	0.01
	(0.02)*	(0.03)
Using codified knowledge	0.07	-0.00
	(0.02)**	(0.03)
Wider innovating	0.07	0.08
	(0.02)**	(0.03)*
Market-led innovating	-0.01	-0.00
	(0.03)	(0.03)
External process modernizing	0.00	0.05
	(0.03)	(0.04)
Human capital	0.02	0.04
	(0.01)**	(0.01)**
International market	0.06	0.08
	(0.02)**	(0.03)**
Turnover in t-1	-0.07	-0.10
	(0.01)**	(0.01)**
Industry dummies	Included	Included
Constant	0.70	0.98
	(0.09)**	(0.19)**
Observations	6,036	3,462
R-squared	0.06	0.07
F-statistic	7.25	3.48

Regression method is OLS. We compute robust standard errors.
Source: Frenz and Lambert (2012) Innovation Dynamics and the Role of the Infrastructure, Department for Business, Innovation and Skills, Occasional Paper No. 3.

Several of the modes variables, and the human capital indicator, appear as significant in the equations representing growth over the period preceding the financial crash. The methodology of creating summary ‘modes’ indicators and combining them with variables for human capital appears successful and can profitably be extended using the wider range of human capital measures in the UKIS 2011.

Innovation modes and skills

The new variables of central importance to this report are those representing the employment of particular skills and enable integration of this extended set of human capital indicators with the mixed modes models. Hence the modes developed for 2006-2008 have been re-estimated with the UKIS 2011 data(using the same or congruent variables – in particular the wider innovation variables are a little different in UKIS 2011) to investigate the complementarities between skills and other innovation system variables.

First, the modes or strategies have been re-estimated using all of the skills variables in UKIS 2011 using exploratory factor analysis and applying the basic Eigenvalue test for determining the number of factors. This results in a set of 7 modes, including the 5 types that emerge from the UKIS over several years, - IPR and own technology based, codified information based, wider or managerial innovation based and process modernisation. The two additional modes are design skill led and S&T skill led, where the S&T skills are science/engineering and maths/stats. The design skill mode loads especially heavily on graphics and web design skills, but also on software development and object and service design. The latter has a secondary loading in the IPR-Tech modes, together with design investment propensity.

An alternative formulation constrains the number of modes to six, since inspection of the analysis of variance in the factor generating process indicates that the seventh mode adds only modestly to the share of variance explained, so that a more parsimonious, 6 factor solution is justified. This, our preferred variant is set out in Table E.8 which shows the rotated factor loadings, with highlighted higher loadings that serve to identify and characterise the modes. Of the six modes, five emerge as quite consistent with the set broadly identified as common across a range of countries in the OECD project. But a new mode based on design-related skills is identified which shows some correlation with the use of copyright protection but less with formal design-related IPR. Science and Technology skills unsurprisingly are correlated with other Technology indicators in a revised IP-Tech mode. The pure design skill of product and service design shows a secondary loading with the technology mode, again emphasising that design is a complementary resource for technological innovation as well as a source of non-technological creativity.

Table E.8 Estimation of mixed modes, with all specific skills, 2008-2010.

Modes *Variables feeding into the modes*	*Mode 1* Technology and IP driven	*Mode 2* Codified knowledge	*Mode 3* Wider innovating	*Mode 4* Design skills driven	*Mode 5* Market facing	*Mode 6* External process modernizing
New product	0.2	0.0	0.1	0.1	0.8	0.0
New process	0.1	0.2	0.4	0.1	-0.3	0.5
New-to-market product	0.4	0.1	0.1	0.1	0.6	0.3
New business practice	0.1	0.2	0.7	0.0	-0.1	0.2
New management technique	0.0	0.1	0.8	0.1	-0.1	0.1
New business structure	0.1	0.1	0.7	0.1	0.1	0.0
New marketing strategy	-0.1	0.1	0.7	0.2	0.3	-0.2
In-house R&D	0.7	0.3	0.3	0.1	0.2	-0.1
Bought in R&D	0.5	0.2	0.4	0.1	0.2	0.1
Machinery, equipment and IT	0.2	0.1	0.3	0.1	0.1	0.5
Training	0.3	0.1	0.5	0.0	0.1	0.3
Design expenditures	0.5	0.2	0.3	0.2	0.3	-0.1
Marketing expenditures	0.2	0.2	0.5	0.2	0.5	-0.2
External innovating	-0.3	0.0	-0.1	0.1	0.4	0.6
Cooperation	0.4	0.6	0.2	0.1	0.0	0.1
Info. from other businesses	0.0	0.8	0.0	0.2	0.0	0.0
Information from universities	0.3	0.8	0.1	0.1	0.0	0.0
Standards	0.0	0.9	0.0	0.1	0.1	0.0
Publications	0.2	0.8	0.1	0.1	0.1	0.1
Patents	0.9	0.2	0.0	0.0	0.1	-0.1
Design right	0.8	0.0	0.1	0.2	0.1	0.0
Copyright	0.6	0.1	0.1	0.3	0.1	-0.1
Graphic Artists	0.1	0.1	0.1	0.9	0.1	0.0
Design of objects and services	0.5	0.1	0.0	0.6	0.1	0.0
Multi-media/web	0.1	0.1	0.1	0.9	0.1	0.0
Software development	0.3	0.1	0.1	0.7	-0.1	0.2
Engineering/applied sciences	0.7	0.2	-0.1	0.1	-0.1	0.2
Mathematics and statistics	0.5	0.1	0.0	0.4	-0.1	0.4

Regression results: business performance

These skills inclusive modes can be used as explanatory variables in performance equations and we turn now to a set of regression models that relate indicators of performance to the skills inclusive modes of innovation. The dependent performance variables reported are: Productivity Level in 2010; Growth in output from 2008 to 2010 and Growth in Employment from 2008 to 2010, all computed from the UKIS 2011 and expressed in Logs. All of the reported equations have sector dummies (not reported) and allow for business size using log of employment.

It is important to note business output and employment growth might be negative over the period, due to the recession, but positive and significant coefficients on any of the explanatory variables indicates that they have at least an offsetting effect and are associated with output or employment growth greater than it would otherwise have been. The growth indicators cover the period of the major recession following the global financial crash, so that positive growth effects are a particularly strong evidence of the role of innovation in performance. We present, in Table E.9 , a model of productivity level (Sales per head) with the shares of graduates, included as explanatory variables. In general most modes show positive and significant 'impact' on productivity, although this is less frequently the case for the 'market facing' modes, as do the shares of graduates, although with some exceptions. For the more demanding tests of impact on growth of output or employment, modes except for market facing record positive and significant correlation with growth of output and of employment, but the shares of graduates do not add to this impact significantly. This is in contrast with the earlier results, where the graduate share was significant. The new, more specific skills variables, in conjunction with complementary assets and capabilities, represented by the modes, have better explanatory value in performance equations than the share of graduates.

Table E.9 Regression model of productivity level in 2010, on modes and graduate shares

Productivity	Coef.	Std.Err
Technology and IP driven	0.383**	0.049
Codified knowledge	0.148**	0.027
Wider innovating	-0.009	0.032
Design led driven	0.247**	0.030
Market facing	-0.107	0.032
External process modernizing	0.151**	0.035
Employment	0.937**	0.009
Share of science and engineering graduates	0.005**	0.001
Share of other graduates	0.007**	0.001
R-squared = 0.716		

Regression method is OLS. We compute robust standard errors. Regressions control for industry and enterprise size.

The design skill led mode retains high significance while the shares of graduates in the labour force are also significant, with non S&T disciplines exhibiting a higher co-efficient and t ratio than S&T graduates. Adding graduate shares indicators reinforces the importance of human capital in business performance when measured by the level of productivity, which is some support for the hypothesis from the skills literature that higher level skills – here proxied by the share of graduates – are needed to manage more complex innovation processes.

The joint significance of skills, higher level skills and codified knowledge as explanatory variables can be interpreted as support for the need for absorptive capacity, here measured by skills employment, when utilizing externally generated knowledge. Currently observed wider innovation is not, though significant, which lends some support for the idea, found in the management and innovation literature than managerial innovation may have a negative effect on current productivity by diverting management attention to the internal change process.

Growth of Output

Growth (in at least relative terms) during the recession was promoted by the use of all the modes except for market facing, with the design skill led mode showing a very significant and substantial co-efficient. Adding the graduates' variables (not shown) does not increase the explanatory power of the equations, suggesting that the contribution of human capital to growth is captured by the specific skills indicators, while the managing complex innovation effect is manifested in productivity rather than growth, at least in the, rather exceptional circumstances of a major recession. The wider innovation dominated mode is, though, correlated with growth, which appears as further confirmation that this type of innovation has rather more long-term effects on performance.

Table E.10. Regression model of growth of output, 2008 to 2010 on modes and graduate shares

Change in turnover	Coef.	Std.Err
Technology and IP driven	0.229**	0.043
Codified knowledge	0.140**	0.024
Wider innovating	0.129**	0.024
Design led driven	0.229**	0.025
Market facing	-0.033	0.024
External process modernizing	0.161**	0.026
Turnover in 2008	-0.131**	0.011
R-squared = 0.112		

Regression method is OLS. We compute robust standard errors. Regressions control for industry and enterprise size.

Employment Growth

Growth in employment during the recession exhibits a very similar pattern to output growth, with all modes, with the exception of market-facing, including the design skill led form, exhibiting positive and significant "impact" although the co-efficients are very small- in the case of design- skill led strategy, around one third of the value in the output growth equation. However the design skill led co-efficient is larger and more significant than that on IP-Tech, although somewhat smaller than that on wider innovation, a further confirmation that skills inclusive innovation strategy can pay off for businesses and for the national economy. Again the codified knowledge and skills led modes are both significant, in line with the absorptive capacity interpretation.

Table E.11 Regression model of growth in employment, 2008 to 2010 on modes and graduate shares

Log Employment Growth	Coef.	Std. Err
Technology and IP driven	0.055**	0.019
Codified knowledge	0.050**	0.011
Wider innovating	0.089**	0.013
Design led driven	0.064**	0.012
Market facing	0.018	0.014
External process modernizing	0.072**	0.014
Employment 2008	-0.044**	0.005
R-squared = 0.0435		

Regression method is OLS. We compute robust standard errors. Regressions control for industry and enterprise size.

Graduate shares of employment variables are again not significant and are not reported.

Design Indicators

- *Research question: How do design skills and design investment combine to affect innovation, productivity and growth and is there a well-defined "design led" innovation category.*

The UKIS has previously included a question of expenditure on design for the purpose of product and process innovation, whereas the new variables concern the employment of the design-related skills whether or not this is directly related to immediate innovation.

Surveys of the industry and of users by the Design Council have also helped to establish that the design is extensively used for innovation and other strategic business purposes.

Design is multi-faceted and that there is no consensus within the discipline itself, or amongst external commentators, on what should be included in or excluded from the scope. This complexity carries over into the field of measurement of design activity in the economy and the economic, societal and other benefits that arise from using design, from using more design or from using it better. One approach to pinning down design for economic measurement purposes is simply to adopt an investment framework - the £ spent on design by economic agents and included in business of national accounts would then be the "value of design" as input to economic and social activities.

One perspective on establishing the scale of design activity in the UK has been pursued in studies carried out by Imperial College and the Office for National

Statistics, originally sponsored by the Treasury and recently developed as a major part of the project at NESTA to develop a UK Innovation Index. The approach is based on measuring market sector expenditure on the creation of intangible assets, including Design alongside R&D, Organisational Capital and Training. The estimate of design expenditure in the pilot NESTA index is based on surveys such as the Annual Survey of Hours and Earning, which covers those self-identified as designers. The first round of this line of research suggests that design investment amounts to around £ 20 billion, which can be compared with £15 billion on formal R&D activities by business. As a further development of the intangible assets approach a new survey of businesses by ONS, working closely with Imperial College economists has sought to quantify their intangible investment directly. This led to estimates of design investment as intangible asset formation that differ significantly from those quoted above, which are derived from more indirect information. Using appropriate weights, the survey results can be used to estimate total business investment in these intangibles in 2009 and design spending was estimated at around £1bn. The survey also found that around 10% of UK firms reported design investment, slightly higher than the 8% who reported R&D spending. These shares are considerably lower than those reported in the UK Innovation Surveys, which consistently find around 20% of respondents reporting spending on design, and a similar proportion with spending on R&D.

In successive UKIS, the 20% of respondents who report that they pursued direct design activity in their product and process innovation over a three year period also reported aggregate expenditure in the final survey year of around £ 2.0 bn. Other indicators of design in the survey imply some "hidden" expenditure and a rough estimate of the level of total expenditure on design in product and process, taking account of hidden design, expenditure could be around £5bn per annum. This is lower than the market sector expenditure on design recorded in the Design Council's Business of Design Survey, at around £11bn over the same period. One implication is that in some firms their design functions and spending are not fully embedded in their core innovation strategies, but seen largely as an addition to innovation is the sphere of marketing and communicating.

The Design Council has also surveyed design using businesses, to identify the functions that employ design and designers While marketing is the most frequently reported use, significant shares of firms also apply design in R&D, product and service development and business planning.

Table E.12 Survey of design using businesses

In which of the following areas does your firm use design?	%
Internally facing functions	39
Externally facing functions	62
Business planning	19
Marketing	71
Research and development	27
New product or service development	49
None of the above	10
Base	*1414*

Source: Design Council 2008 Business Research

Design and Service Innovation

An area of on-going debate in innovation studies and measurement is how to deal with service innovation. The importance of the subject derives in large part from the dominance of the service sector and service products in the aggregate economic indicators such as GDP across developed economies, which stands in contrast with the extended perception that services are still "second class" citizens in innovation activities and outcomes and that "real" innovation remains in the production of physical goods, industrial processes and the R&D that supports or drives them. The analysis of modes of innovation in the service sector and the introduction of service innovation has been the subject of a number of recent studies. Due to data limitations, these inquiries have been limited in their ability to assess the potential for design to be a significant determinant or form of service innovation.

A Design Indicator?

As noted, the innovation survey includes a number of variables that reflect design activity, including, as well as the design specific design skills, investment in "all forms of design" and some Intellectual Property indicators that are design based, including the Design Registration property right and the strategic protection option of design complexity (to increase the difficulty and cost of copying of a new product by competitors. These are highly correlated.

For this Research Question, we have explored the results of using a unified design variable by collapsing these indicators together to construct a composite "design user" variable, and have repeated some of the analyses of the links between the types of innovation and the determining variables, but substituting the composite indicator for the design skills, design investment and design based IP variables. This tests if a "design" variable has more explanatory power in the equations on innovation propensities. In sum, the degree of overlap between the design indicators leads to the composite indicator showing a statistical relationship with the innovation variables that is close to the sum of the coefficients and their significance when design investment and the specific design-related skills introduced separately, so we have not reported the results of the experiments here.

Modes
We have re-estimated the mixed modes substituting the composite design indicator for the distinct design-related variables. The substitution leads to design loading with IP and R&D variables in the mode we have termed IP-Tech, while the S&T skills variables now form a distinct S&T led mode, in contrast to our preferred mixed modes model, where they loaded in the IP-Tech mode. This result tends to confirm the analyses that identify design skills and design investment as acting both as complements to technology and also to less technological forms of innovation – in ways that can be usefully seen as integrating inputs and market demands, and in some cases, acting as one of the sources of creativity.

From the preceding analysis, there seems little to gain in understanding the role of design in innovation from reducing the design skills, design investment and design IP indicators down to one composite variable, apart from parsimony in equation building. In many cases, the scale of the effect is less for the composite variable, so that parsimony is at the cost of a loss of explanatory power.

But the substantial and statistically well determined correlation between design – including skills and investment – and most innovation indicators, reported above confirms the results of the Design Council surveys that design is a significant capability across the range of innovation outcomes. This is in contrast to the way design is understood and measured in mainstream innovation analysis and metrics systems. For example, the international standard for innovation measurement, the Oslo manual recognizes that design is part of the complete innovation process, but, for measurement purposes, stresses its role in marketing innovation, as a way of varying presentation of a product, without affecting its functional or user characteristics.

The analysis using mixed modes of innovation also finds that the design skill led mode has positive and significant “impact” on the range of economic performance indicators. The model presented there also conclude that design investment for innovation complements IP and technology relate variables, reinforcing the role of design as a link between (technological) creativity and applications in use.

Conclusions on Design
We have presented a range of analytical models that relate innovation to design indicators and economic performance to modes of innovation that are characterized by or strongly feature design. The size of the coefficients and the degree of significance confirm that design can be seen as a key creative element in innovation in firms and in the national innovation system, where it also plays a leading role in linking other innovation determinants with business, market and economic outcomes. This pervasiveness is in stark contrast with the frequent treatment of design as an ancillary, after the main event element in innovation, suggesting that in analysis and evidence based policy making, design-led can usefully be treated as a well defined category.

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